A Serious Games Development Environment

BY

IVAN CARMOSINO

PH. D. THESIS

TUTOR: PROF. RICCARDO BERTA

UNIVERSITY OF GENOA

MARCH 2018

Index

INTRODUCTION 4

EDUCATIONAL SERIOUS GAMES 8

HISTORY, APPLICATION DOMAINS AND TAXONOMIES 11

SG DEVELOPMENT, A MULTIDISCIPLINARY CHALLENGE 14

PEDAGOGICAL THEORIES AND MODELS 15

SG MECHANICS AND MODELS THROUGH EXAMPLES 19

THE GAMES-AS-A-SERVICE APPROACH 26

DEVELOPING A SG NOWADAYS 27

SERVICE-ORIENTED ARCHITECTURE (SOA) IN GAMES 27

THE AS-A-SERVICE APPROACH 31

THE COMPLETE VISION 33

THE AS-A-SERVICE PLATFORM 36

BARRIERS AND OBSTACLES 38

THE SAND-BOX SERIOUS GAME MODEL (SBSG) 40

SBSG CONCEPT 41

THE VIRTUAL WORLD 43

TASK (MINI-GAME) TYPOLOGIES 46

THE TREASURE HUNT MODEL 47

THE SERIOUS GAMES DEVELOPMENT ENVIRONMENT (SGDE) 49

LITERATURE ANALYSIS 50

SGDE ARCHITECTURE 52

THE SUPPORTED GAME MODEL 52

THE INVESTIGATION MODEL DESCRIPTOR 54

MINIGAMES 61

THE PARSER MODULE 66

GAMES EXAMPLES 69

CAN'S CRIME EXAMPLE 69

DRAWEVA 72

EXPERIMENTAL RESULTS 77

EXPERIMENT DESCRIPTION 78

RESULTS 79

DISCUSSION 80

CONCLUSIONS 82

REFERENCES 84

Chapter 1

Introduction

Education has become an emergency in our societies. Education involves everybody, at every age. However, it is fundamental for young people and requires responsible adults that introduce each child or young man to the totality of the reality. Education, thus, has a very broad spectrum and cannot be guaranteed by single tools. But it is a reasonable question to investigate what Information and Communication Technologies tools can be developed and used in order to favour educators in their mission. In particular, there are some aspects of education – notably, learning and training - that seem particularly suited to computer-based support. And in this regard, some game technologies seem effective and promising, also because they seem to address several e-learning problems such as high dropout rates due to frustration and the lack of motivation to continue studying [Prensky, 2000; Yessad, 2010].

The potential of Serious games (SGs) - games that use pedagogy to infuse instruction into the game play experience [Greitzer, 2007; Gee, 2007] - is relevant, because a large and growing population is familiar with playing games, that can present users with realistic and compelling challenges, highly stimulating their information processing capabilities and capturing their concentration span for long duration. Games embody well-established principles and models of learning. For instance, games are effective partly because the learning takes place within a meaningful (to the game) context.

What you must learn is directly related to the environment in which you learn and demonstrate it; thus, the learning is not only relevant but applied and practiced within that context (Situated cognition). Researchers have also pointed out that play is a primary socialization and learning mechanism common to all human cultures [Van Eck, 2006]. Literature [Menn, 1993] claims that students can only remember 10 percent of what they read, but almost 90 percent, if they engage in the job themselves, even if only as a simulation.

Good SGs challenge players with immersive situations, providing concrete, compelling contexts where the player gets involved. This is important to motivate learners and also to show the concrete relevance to everyone's life of subjects (e.g., maths and physics) that are frequently considered as cold and abstract, but whose applications to improve our understanding (and prediction) of the world and its processes are surprising and give satisfaction to students. Moreover, SGs can provide an excellent context not only to acquire and test knowledge and skills, but also to closely examine an environment without the barriers of time and space (and any other type of costs), thus can be gyms where new knowledge, practices and solutions can be developed. Play, in fact, supports players in exercising five kinds of freedom (freedom to fail, experiment, fashion identities – possibility to experience a situation from multiple perspectives [LoPiccolo, 2005] -, of effort and interpretation), that can complement formal learning by encouraging learners to explore various situations [Klopfer, 2009]. SGs can be multiplayer, favouring team-building and cooperation in facing issues, shaping real communities of learners. The widespread diffusion of mobile gaming is opening further perspectives also for learning and socialization (e.g., [Tian, 2010]).

Games provide immediate feedback, that may be efficient for procedural learning. Virtual environments and simulations are effective over non-computer methods, as they allow for high levels of fidelity and an immersive experience

[De Freitas, 2009]. This is expected to be ever more important in particular to support training, particularly in areas of training where learning fade could be critical and involve the loss of lives, such as in emergency response training [Jarvis, 2009]

Despite their potential, the market for educational serious games (SGs) is still limited, partly because of the high design and production costs. In this thesis, we propose a framework called “Serious Game Development Environment” (SGDE) for efficient development of a special class of SGs, the Sand-Box Serious Games (SBSGs). SBSGs invite players to perform cognitive tasks contextually, while exploring information-rich virtual environments.

The framework provides a description template and a set of web services that allows developers to define the items to be investigated in a structured and straightforward way by players who are typically asked to perform some tasks in relevant points of the environment, in order to get (by doing) or test knowledge about some specific subjects. The descriptor is processed at runtime by a enhanced version of a game engine, which is responsible for setting up the virtual environment and managing the gameplay accordingly, and a set of web services to support multiplayer modality, online chat among players and score computation. The goal is to make the game development easy also for knowledge domain experts with no programming experience, and to separate the content from the code, thus providing a modular work environment for the production, management and maintenance of games.

After describing the framework, the thesis presents its application to the development of two real example: “Can's Crime” (a SG teaching industrial production processes) and “Draweva” (a SG to teach leadership skills to managers). Data from a preliminary pilot (realized with game developers) have shown that using the framework allows a significant reduction in development time. Moreover, creation of an abstraction level over the game engine allows improving structured content organization, which is in turn expected to enhance maintainability and modularity. I argue that the same approach could be employed to other game formats, especially in the emerging context of developing "games as services"

The remainder of the thesis is organized as follows. The next chapter (2) provides the background on educational SGs and discusses the state of the art. Chapter 3 presents the new approach of "games as-a-services". Chapter 4 describes the supported game model, while chapter 5 presents the descriptor of the SGDE framework. Chapter 6 shows the application to the development of several real games. Final chapters (7 and 8) present a preliminary assessment of the benefits and the conclusions of this research work.

Chapter 2

Educational Serious Games

Serious Games (SGs) - games designed for a primary goal different from pure entertainment [Prensky, 2003; Gee, 2003; Zyda, 2005; Bellotti, 2010] - are receiving a growing interest for education. Exploiting the latest simulation and visualization technologies, SGs are able to contextualize the player's experience in challenging, realistic environments, supporting situated cognition [Watkins, 1998]. Play supports players in exercising freedom that can complement formal learning by encouraging learners to explore various situations [Klopfer, 2009], with limited barriers of space and time. Cost is another key factor, especially for SGs providing simulation of complex/costly environments [Kincaid, 2009] and of dangerous/critical situations [Jarvis, 2009].

SGs can be multiplayer, favouring team-building and collaboration/cooperation in facing challenges and issues [Connolly, 2007; Islas Sedano, 2013; Wendel, 2013]. The widespread diffusion of mobile gaming is opening further perspectives also for learning and online socialization (e.g., [Parsons, 2012; Chi-Husiung, 2012]). Furthermore, a large and growing population is increasingly familiar with playing games. SGs do not target exclusively power-gamers (typically young males fond of First Person 3D immersive experiences). Power-gamers represent just a subset of the gaming community, while other types of players (e.g., social, leisure, occasional) are increasing in number. This audience enlargement has been enabled by new typologies of games (e.g. brain training games, intellectual challenges such as Professor Layton and the Curious Village and Phoenix Wright: Ace Attorney) and by new modalities of interactions (e.g. online collaboration, verbal commands, gesture-based control, social environments, family gaming). Moreover, several new games (e.g. mobile, some consoles and new interaction modalities) are inexpensive to produce and run on low-cost computational platforms. Fig. 1 provides a set of screenshots from state of the art SGs.

Fig. 1 Snapshots from state of the art sample serious games. Clockwise from top left: the Siege of Syracuse, RescueSim, Simport, Building Detroit

Business data argue for a favourable trend for SGs. The IDATE 2012 report estimates the global market of SGs at 2.35bn €, with steady growth and huge potential [IDATE, 2012]. Positive trends for SGs and gamification (which includes the use of SGs) are also provided by other market and expert analysis and surveys [Pew Research Center, 2012; Deloitte, 2012; Gartner, 2013]. Performing a survey with e-learning professionals and experts, and comparing outcomes with literature review, [Mitchell, 2004] stresses a “positive view”, as SGs are perceived as “de facto effective learning environments because games challenge and support players to approach, explore and overcome problems”.

Use of SGs for education and training involves also some concerns. [Clark, 2003] argues that intended learning outcomes and game objectives and features (e.g., difficulty level, duration, aesthetic, and interaction modalities) might conflict among each other. The ‘suspension of disbelief’, typically happening in a game, may negatively influence the learning processes. Certain socio-demographic groups may feel excluded and frustration may be created by usability issues and competition. There is a risk of stressing extrinsic motivation towards an educational topic (through competition, rewards, badges, etc.), with respect to intrinsic motivation, that is fundamental in the long-term. Developing AAA commercial games is extremely expensive, and SGs cannot afford such budgets. Thus, the term “game” may create excessive expectations in the users. Moreover, [Tashiro, 2009] reports that while there is insufficient evidence to know if current serious games may improve healthcare education, there is evidence that they may inculcate inadequate clinical pattern recognition. All these observations highlight the fact that SG design is a complex challenge, involving a variety of dimensions, and that use of SGs in educational settings should be properly organized.

Summarizing, there is a consensus in the scientific community about the instructional potential of games, mostly because they are considered motivating (e.g., [Iacovides, 2009; Kirriemuir, 2004]). Few tests have shown the educational value in particular in the business/management field. But, in general, most of the authors agree that more extensive tests are to be performed (e.g., [Qin, 2010; Petrasova, 2010; Aylett, 2009; Rebolledo-Mendez, 2004]). Some experiences highlight the importance of games for awareness raising (e.g. for societal issues). However, stressing the emotive aspect, that is interesting for some types of games – in particular for advertising -, may be misleading for proper education. The concern is emerging that “we are just beginning understand when and how games promote learning, and why” [Johnson, 2005]. In particular, there is a need for scientific and engineering methods for building games as means that provide effective learning experiences. This is the starting point for the research works of this thesis: how to design a framework for the efficient development of SGs.

Before to introduce the developed framework, in this chapter we will provide a brief overview of the SG history, application domains and taxonomies, some detail on the underlying pedagogical theories and models and their implications for SG design.

History, application domains and taxonomies

Following from the Platonic differentiation between games for fun and games for learning, the term "serious game" was firstly used in [Abt, 1970]. The “serious game” term in a digital context was firstly used in 2002, with the start of the Serious Game Initiative lead by David Rejeski and Ben Sawyer in the US.

SGs were initially conceived to train people for tasks in particular jobs, such as training army personnel [Zyda, 2003] (Fig. 2 shows a couple of screenshots from the famous America’s Army), or salesmen. The games typically concerned acquisition of knowledge and/or procedural skills and were targeted at a captive audience. With the diffusion of “non-hard” gaming and of new devices (e.g. smartphones, tablets, various types of consoles), a variety of SGs has been rapidly established, for different types of users (students, adults, workers, etc.), applications/goals (instruction, training, advertising, politics, etc.) and implementing different genres (arcade, first person shooter, etc.). In literature, it is possible to find several examples of learning games, showing that uses of SGs now “span everything from advancing social causes to promoting better health to marketing. [...] Advergaming is a popular form of advertisement that delivers commercial messages through games” [Zyda, 2003].

Fig. 2 Snapshots from America’s Army, one of the first SGs, still used for recruitment

Work on SG categorization clearly shows such a variety. Several taxonomies have been proposed in literature that classifies SGs according to different criteria, such as application domains, markets [Michael, 2006], skills [Kirriemuir, 2006; Riedel, 2011], learning outcomes [Egenfeldt-Nielsen, 2006]. The classification proposed by [Sawyer, 2008] that rapidly became a reference, proposed a matrix of two major criteria: market (the application domain) and purpose (initial purpose of the designer). Items in the first dimension include: government, defence, marketing, education, corporate, etc. Items in the second dimension include: advergames, games for health, games at work, etc.

[Kickmeier-Rust, 2007] introduce categories based on the psycho-pedagogical and technical level of games. A hypercube taxonomy has been developed by [Kickmeier-Rust, 2009], highlighting the following dimensions:

- Purpose – ranging from fun/enjoyment to training/learning
- Reality – ranging from imitation of real and fictitious contexts to proving abstract visualizations such as in games like Tetris.
- Social Involvement – ranging from single player games to massively multiplayer games.

- Activity - ranging from active game types (e.g., action games or – even with a physical dimension – the Nintendo Wii game play) to passive game types (where at the end of this continuum the passive perception of a movie is situated).

The website serious.gameclassification.com (3321 featured games, as of January 2018) is a collaborative classification of SGs, which is a reference at world level [Djaouti, 2008; Djaouti, 2011. The selected classification dimensions - that are a clear extension of the model - are:

- Gameplay (game-based vs. play-based – games have fixed goals to achieve; core rules represented by bricks constituting a game)
- Purpose (Education, information, marketing, subjective message broadcast, training, goods trading, storytelling)
- Market (Entertainment, State&Government, Military &Defense, Healthcare, Education, Corporate, Religion, Culture&Art, Ecology, Politics, Humanitarian &Caritative, Media, Advert, Scientific Research)
- Audience (Type: General Public, Professionals, Students; age groups)

More structured databases of educational SGs have been built in projects such as Imagine (www.imaginegames.eu), Engage learning (www.engagelearning.eu), Serious Games Society (www.seriousgamessociety.org). The Serious Games Society taxonomy includes a number of descriptors that are useful for conducting SG studies, including:

- Description/classification (genre, platform(s), application domain, learning curve, effective learning time, play mode, player assessment, provision of feedback, etc.)
- Analysis of game components (UI, rules, goals, entity manipulation, assessment), for a detailed specification of the game mechanisms.

- Pedagogy. The taxonomy is organized in two major sectors: 1) Theoretical frameworks: constructivism, objectivism, personalism, etc. and 2) Outcomes: cognitive; psycho-motorial; affective; Soft-skills.
- Deployment ("Use of the game"), specifying settings such as: target users (age, specific categories of persons, school level, etc.); target topics; prerequisites for use (if any) (cognitive, content-related, domain related, psychomotor, etc.); context of use (e.g., formal education, corporate training and other)
- Technologies employed for the development. Game engine, development tools/platforms, AI algorithms.

Metrics are also provided to allow an assessment of SGs by experts along dimensions such as learning effectiveness, efficiency, fun level, etc.

SG development, a multidisciplinary challenge

In order to develop and deploy effective tools for learning, it is necessary to consider all the stakeholders (users, educators, families, researchers, developers/industries) and the whole cycle from research to market and vice-versa. From a scientific point of view, it is necessary a complex mix of disciplines and technologies, such as: Artificial Intelligence (AI), Human-Computer Interaction (HCI), networking, computer graphics and architecture, signal processing, web-distributed computing, neuroscience. These technologies are to be developed and exploited in a target-oriented multidisciplinary approach that puts the user benefits at the centre of the process. Given the instructional goal, SGs should provide quality contents on the target domain and their development should be strongly grounded in proper educational foundations [Greitzer, 2007].

Fig. 3 sketches the complexity of the various disciplines and factors involved in proper SG development. In the reminder of this chapter we discuss more in depth some of the most important topics.

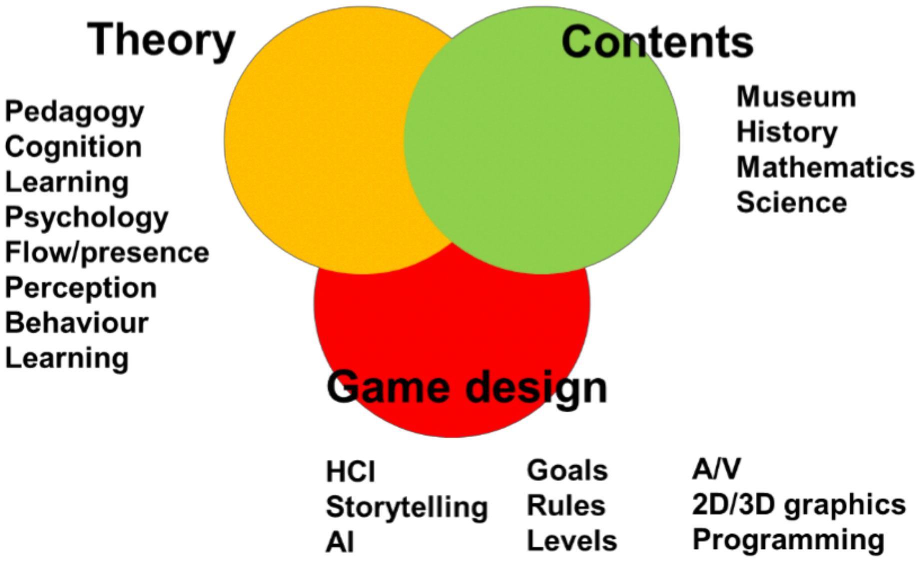

Fig. 3 The three kernels of SG design

Pedagogical theories and models

Games are “per se” motivating – and can be successfully employed with this aim. However, instructional effectiveness involves other aspects that can be analysed at the light of the pedagogical theories. The goal of this section is not to provide an overview of such theories, but to present and discuss the main aspects involved in SG design and their implications in order to guide the subsequent design of the tool developed in the thesis.

The design and use of digital serious games has a certain theoretical foundation in the constructivist learning theories, that stress that knowledge is created through experience while exploring the world and performing activities [Dewey, 1933; Montessori, 1946; Kolb, 1984]. Implications on game design involve the creation of virtual environments, typically 3D, where the player can gain knowledge through exploration and by practice (e.g., manipulating objects), possibly in collaboration with other people.

Constructivism stresses the importance of the learner to build his own knowledge. However, [Kirschner, 2006] argues for the importance of guidance, in particular for novices. They refer to the cognitive load theory (CLT) [Sweller, 1988], stressing the need of explicit teaching because of the limitations of the working memory. Analysing user experience of Crystal Island, [Rowe, 2010] reports that "high-achieving science students tended to demonstrate greater problem-solving efficiency, reported higher levels of interest and presence in the narrative environment, and demonstrated an increased focus on information gathering and information organization gameplay activities". However, "lower-achieving microbiology students gravitated toward novel gameplay elements, such as conversations with non-player characters and the use of laboratory testing equipment". Observing the gameplay, the authors noticed that "high-achieving students tended to utilize more traditional science resources such as textbooks and worksheets while attempting to solve the presented mystery. In contrast, low-achieving students employed the help of expert non-player characters and virtual lab equipment to aid in their quest". These observations seem to stress the fact that learning is a complex activity that requires graduality and needs several steps, that have to be supported by various tools (e.g., paper and digital, reading and writing, etc.) and generally have to be guided, possibly by an adult, in order to be meaningful/compelling for the learner and not to waste time and energies. Maps, landmarks, contextualized helps, objectives' lists with status information are game elements that could be employed in order to support avoidance of player's cognitive overloading.

Another important theory is flow, based on Csikszentmihalyi's foundational concepts [Csikszentmihalyi, 1990]. Flow was first employed to measure engagement in an educational game in [Chen, 2004]. [Sweetser, 2005] drew together various heuristics present in the literature into a concise model, the GameFlow, consisting of eight elements: concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. As the result of more than three decades of commercial competition, most of today’s video games deliberately include and leverage the eight components of Flow [Chen, 2007]. [O’ Broin, 2011] highlights that most games adequately meet two primary elements of flow - clear goal and feedback - but the balancing of game challenges and player skills is often lacking. In order to maintain a user’s Flow experience, the game’s activity must balance the inherent challenge and the player’s ability to address and overcome it. If the challenge is beyond that ability, the activity becomes so overwhelming that it generates anxiety. On the other hand, if the challenge fails to engage the player, the player loses interest and quickly tends to get bored. However, designing such a balance becomes a greater challenge as the size of the potential audience grows, which is the typical case of video games. Most games presently offer only a single narrow, static experience, which might keep the typical player in the Flow but may not be fun for the hard-core or the novice player. Several choice possibilities should be given to the player, adapting to different users’ personal Flow Zones, which is costly and may interrupt the user’s experience. The best way for designers to avoid these counterproductive situations is to embed the player choices into the core activities of the interactive experience and/or to make the game automatically adaptive [Lopes, 2011] in particular through player state assessment [Liu, 2009]. A consequent research issue is how to measure the player flow status during the game, possibly with no invasiveness, for instance through neuro-physiological signal processing [Berta, 2013]. In fact, using questionnaires (either on paper or electronic) requires interrupting the game and leads to variable subjective values. Moreover, participants may report their belief in general, but may not reflect the experiences of the moment while playing [Chiang, 2008].

Personalism tends to consider education as a human relationship between a child (learner) and an adult (teacher) who introduces to reality [Maritain, 1985]. Centrality of the person stresses user-cantered design (e.g., [UPA, 2008]). Other specific implications for SG design may involve: presence of real-world hooks (e.g., territorial gaming) and references inside the game, possibility of supporting a dialogue between learner and teacher, game analytics able to provide detailed information about the player's performance that could be analysed by the teacher in order to advise on possible improvements and corrective actions.

Several learning models have been employed to inspire SG design and assess validity of SGs. Among the knowledge models, we highlight the Nonaka SECI model [Nonaka, 2000], which is mentioned as a theoretical basis for the use of SG-based workshops, at least in the fields of business, management and manufacturing [Bastos, 2012], and the Kirkpatrick's "Four Levels of Learning Evaluation", which is a popular learning impact assessment model, involving the following levels: reaction, learning, behaviour, results [Kirkpatrick, 1998].

Two pedagogical models look complementary, simple and particularly useful to analyse SGs [Baalsrud Hauge, 2013] (see Fig. 4): the Revised Bloom Taxonomy, which is the most popular cognitive approach to SG evaluation; and the Kolb's Experiential Learning model, which systemizes the work rooted on Piaget's cognitive developmental genetic epistemology, on Dewey's philosophical pragmatism, and on Lewin's social psychology, putting the experience at the centre of the learning process. Good SGs and simulations should allow users to make significant experiences, thus typically supporting the experiential learning pedagogical paradigm.

Cognitive competences in the Bloom taxonomy (Bloom, 1956)	Learning goals in the Revised Bloom taxonomy (Anderson and Krathwhol, 2001)
Knowledge	Remembering
Comprehension	Understanding
Application	Applying
Analysis	Analysing
Synthesis	Evaluating
Evaluation	Creating

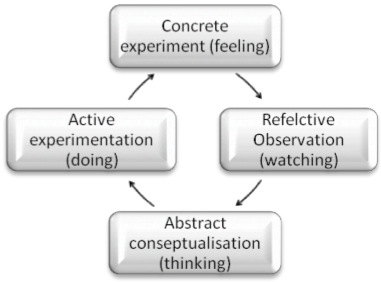

Fig. 4 The Revised Bloom taxonomy and the Kolb's learning stages

SG mechanics and models through examples

This sub-chapter intends showing the main mechanics and models that are used in SG designs, by analysing a set of well-established SGs and formats. From this analysis we have devise the main features of the tool developed later.

CancerSpace (see Fig. 5) is a game format that incorporates aspects of e-learning, adult-learning theory, and behaviourism theory to support learning, promote knowledge retention, and encourage behaviour change [Swarz, 2010]. CancerSpace's design encourages self-directed learning by presenting the players with real- world situations about which they must make decisions similar to those they would make in clinics. The targeted users are professionals working in community health centers. The authors stress the main peculiarities of the game with respect to a mere collaborative 3D e-learning environment. The first point is about role-playing: the user has to help the clinical staff evaluate the clinical literature, integrate the evidence into their clinical decision-making, plan changes to cancer-screening delivery, and accrue points correlating to increased cancer-screening rates. The user takes decisions and observes whether the chosen course of action improves the cancer screening rates.

The game includes a small number (four) of patient-provider interactions in which the decider must talk with a patient reluctant to get screened, try to educate that patient, and hopefully get him or her screened. The Decider must negotiate cultural and language barriers as well as the patient's changing attitudes toward screening. The player's conversation choices are evaluated in pre-programmed decision trees, leading to success (the patient decides to get screened) or failure.

Chance is considered an important entertainment and variability feature. To this end, wildcards are implemented, that reflect certain unplanned events common to community health centres such as a budget cut, funding of a grant, or a staff member transferring to another clinic.

Other critical factors for CancerSpace concern the use of audio elements such as buzzers, chimes, and other sound effects, combined with video elements such as quick animations indicating an incorrect answer and a mentor character showing emotions ranging from strong disapproval to strong approval.

To stimulate gameplay, CancerSpace has adapted an award system that motivates players to increase screening rates. The CancerSpace scenarios in which the decider guides the virtual clinical staff are based on research-tested interventions and best practices. Users receive points on the basis of their performance. At each game's conclusion, a summary screen indicates which decisions the player implemented and their effect on the clinic's screening rate.

Fig. 5 Snapshots from CancerSpace and ReMission

Re-Mission 2 is a collection of online games that help young people with cancer fight their disease. Each game puts players inside the human body to defeat cancer, using weapons like chemotherapy, antibiotics and the body's natural defences. The games are designed to motivate players to stick to their treatments by boosting self-efficacy and positive emotions and by shifting attitudes about chemotherapy. A study results show that neural circuits implicated in reward (i.e., caudate, putamen, and nucleus acumens) activated strongly while players were actively playing Re-Mission but not when other players passively observed the same gameplay events. This reward-related activation is associated with a shift in attitudes and emotions that has helped boost players' adherence to prescribed chemotherapy and antibiotic treatments [Cole, 2012].

SGs and Virtual World technologies allow the creation of realistic 3D environments, with full sensory representation and immersion. These environments, populated by players' avatars and by Virtual Human Characters (VHCs) controlled by the computer's Artificial Intelligence (AI). This is the concept of Living Worlds (LWs). In their LW for cultural training in Afghanistan, [Zielke, 2012] indicate several mechanics, starting from the main objective: the player wins by successfully interpreting the environment and achieving the desired living-world attitude toward him. The entire living-world game space is fuelled by the knowledge- engineering process that translates the essential elements of the culture into programmable behaviours and artefacts. For instance, "In Afghan culture, older men have great influence over younger men, women, and children through local traditions and Islamic law". "Ideologically, the guiding principles of Afghan culture are a sense of familial and tribal honour, gender segregation, and indirect communication". All the non-player characters (NPCs) in the game are modelled accordingly. These models control activities ranging from gossiping to daily behaviour such as traffic/errands. The overall social environment is modelled as well (e.g., simulating generation of factions). Winning in the game "simply" requires successfully navigating cultural moves in the game space thus achieving a good overall attitude of the village toward the player.

NPCs are highly realistic both in their aspect and in their movements. Sound is designed keeping into account three dimensions: global (e.g., weather conditions and distance traffic), regional (e.g., a radio in the room) and local (e.g., footsteps, voices).

Another key aspect is assessment, through the underlying 3D Asymmetric Domain Analysis and Training (ADAT) model that allows for analysis of the cultural behaviour exhibited by the player in the game. Conversations and interactions between the NPCs and the player are recorded through a text log to provide game performance analysis. The assessment tool lists all possible choices for player behaviour and conversation, highlighting both the player's choice and the most culturally appropriate response. The tool provides scores on the opinion of the player at the NPC, faction, and village level. Additional comments can be provided that highlight the player's weaknesses, explaining why a particular response is most appropriate. Feedback is thus provided to improve future performance.

Fig. 6 Snapshots from Real Lives 2010 and SimVenture

Real Lives 2010 (Fig. 6) is an interactive life simulation game that enables you to live one of billions of lives in any country in the world. Through statistically accurate events, Real Lives brings to life different cultures, human geography, political systems, economic opportunities, personal decisions, health issues, family issues, schooling, jobs, religions, geography, war, peace. Compared with a control group, students who played the simulation game as part of their curriculum expressed more global empathy and greater interest in learning about other countries [Bachen, 2012].

Managerial business SGs like SimVenture (Fig. 6), GoVenture CEO and MarketPlace are increasingly being used in higher education. They represent detailed business simulations where users (also grouped in teams) are responsible for managing a company in various market scenarios. A number of performance indicators (e.g., Bank Balance, cash-flow, Company Value, Gross Profit), that are useful for self-assessment, are provided, but it is generally difficult for the player to understand the impact of his choices (e.g. about marketing, personnel, etc.) on those figures. CEO provides a simulation management module through which the teacher can configure different types of inter-team team competition scenarios. Literature highlights that, in this kind of games, the cyclical nature of the game play (simulated business monthly periods of the player's company) can be directly mapped to the sequential steps described by Kolb [Kolb, 1984], such as: experience of the simulation's business scenarios; observation of the player company's results in the simulated month; conceptualization, in order for the player to understand the situation and the decisions to be taken for the next periods; experimentation, through the choice of the parameter values for the next period.

Describing lessons learnt about what makes games useful from a therapeutic point of view, [Gee, 2003] - they designed and user tested stroke rehabilitation games - highlight the importance of the following attributes: ensure playability for a broad range of patients: multimodal input, provide examples, direct and natural mappings; ensure games are valuable from a therapeutic perspective; ensure that users' motions cover their full range, detect compensatory motion, allow coordinated motions, let therapists determine difficulty; ensure that games fun and challenging: audio and visuals are important, automatic difficulty adjustments provide adequate challenge, NPCs and storylines are intriguing. Future steps concern creation of connections with friends and family members, and support of socialization.

Another key aspect for gaming and learning is online collaboration that can involve learners and educators as well [Connolly, 2007]. Collaboration is a key skill for current jobs and practicing collaboration in concrete simulation tasks is expected to be highly beneficial (e.g., [Angehrn, 2009]). While some SGs support collaboration in order to achieve their goal (e.g., [Hannig, 2012]), others, like The Barn's TeamUp [Mayer, 2013] or Escape from Wilson Island, are ad-hoc designed with the main target of fostering collaboration and leadership.

In this thesis, we will abstract a conceptual model – the SandBox Serious Game (see Chapter 3) - which relies on a generalization of task-based learning theory. The model invites players to perform cognitive tasks contextually while exploring information-rich virtual environments. The model defines games (e.g., treasure hunts) that are set in realistic virtual worlds (typically 3D) enriched with embedded educational tasks, which have been implemented as mini-games that can be instantiated out of a set of predefined templates. This approach simplifies the authoring work, allowing an approach similar to the mind-maps concept. Tasks/mini-games allow the player to focus on a specific item/topic in the environment. Each task/mini-game involves very short introduction and conclusion texts that complement and reinforce the task experience through plain verbal knowledge. Compared to reading text, a game forces the player to focus more strongly on problems, which favours knowledge acquisition and retention. Learning complex concepts requires an investigative attitude, which can be spurred by well-designed games. Good design involves usability, graphic appeal, appropriate content, and the presence of connections which a player must discover in the content. Players should be asked to pay attention to and reason about their whole game activity - including the relationships between the game content, the brief introduction, and concluding texts.

Chapter 3

The games-as-a-service approach

As discussed in chapter 2, research has shown the high educational potential of SGs. However, at present, there is a limited offer and market, and SGs are used in niche areas (e.g., competitive simulations in business schools), or for some specific goals (e.g., foreign languages and math in elementary schools). There is still a major barrier to SG diffusion as it is difficult and expensive to develop high-quality games. The SGDE proposed and developed in this thesis, as described in chapter 5, is an attempt to overcome this barrier. However, the approach can be extended with a general games-as-a-service approach, as discussed in this chapter.

The overall goal of the games-as-a-service approach is to allow teachers and trainers to exploit a variety of easily available and usable serious games in their daily educational and training activities. To achieve this goal, it is necessary to perform research to make the functionalities of entertainment industries usable inside non-leisure games, keeping into account the specific educational requirements of SGs. This includes:

- adopt (and adapt) a technology for decoupling the use of a functionality from its implementation;

- insert in the functionalities the parameters to adapt to the user and the content;
- allow non-professional developers (e.g. teachers and educators) to exploit the functionalities to instantiate SGs suited to their specific learning goals;
- find proper business facilitators to allow also small developers to deploy, retrieve and exploit functionalities and SGs.

Developing a SG nowadays

Development of a SG typically involves a company exploiting a game engine like Unity3D Engine or Crytek Engine. Game engines provide key functionalities such as game scripting, event management, graphic rendering, etc. Additional components and libraries are added and re-used in different games, in order to provide specific functionalities (e.g., user profiling, natural language processing, quiz management). Some of these components are available in-house, other from third parties, sparse over the Internet. These components are compiled together and bundled in an executable game, which is downloadable or accessed online by remote users. Some toolkits (e.g., Magellan and Role projects) are available for development of very simple SGs by non-professional users, such as teachers. There are no cloud-based facilities for SG development.

Service-Oriented Architecture (SOA) in games

A Service-Oriented Architecture (SOA) is "a software architecture for building applications that implements business processes or services by using a set of loosely coupled, blackbox components orchestrated to deliver a well-defined level of service" [Hurwitz, 2007]. It is a set of ideas, recommendations, policies and practices for architectural design. One of its goals is to employ modularization and compositionality to achieve flexibility and to enable the reuse of software parts, in an attempt to manage the complexity of large systems [Sprott, 2004], [Aalst, 2007].

The benefits of using adopting a SOA approach in a context are many. Unlike the case of traditional library reuse (or software modules, components, etc.), which requires replication of code, the SOA approach supports the reuse of services themselves. In addition, it supports such a level of abstraction that multiple services can offer the same functionalities, potentially increasing the diversity of services from which to choose. Furthermore, SOA establishes contracts between endpoints, placing formal obligations between consumer and provider. A single instance of a SOA can serve multiple client-organizations (tenants) with multi-tenancy (in contrasts with multi-instance architectures where separate instances operate on behalf of different client organizations). Finally, the delivery of functionalities has to be made in an appropriate level of granularity, not so coarse and thus without flexibility, and not so fine that it affects the service's effective application [Sprott, 2004]. Web services are the set of protocols by which the services in SOA architectures can be published and used. An implementation that complies with known web service standards, such as representational state transfer (REST), has the additional benefit that the applications are standardized, technology/platform neutral and they can be discovered and used automatically.

There are, nevertheless, challenges in adopting a SOA approach for a new context like SGs design and implementation. Quality assurance and testing module integration tends to be more difficult when developing SOA applications. In addition, a service can be practically unusable if its interfaces lack clarity or the documentation is not clear. Finally, extra attention has to be given to service descriptions, as they are the way to advertise the capabilities, interfaces, behaviour and quality of a service, providing the required information for discovery, selection, binding and composition with other components [Papazoglou, 2007]. A SOA approach can bring to serious game development the potential benefit of scalability and usage dependent payment model that became common with Cloud Computing. It also makes it possible to access serious games from common devices, no longer dependent on the quality of gaming hardware. In addition, providing pervasive gaming experiences becomes easier, as support for different platforms is highly simplified if the core of the gaming experience is provided via a service in the cloud [Hassan, 2012]. Although there are clear benefits in employing service-based architectures to serious games development, there are limited examples in the literature of deployments of SOA-based SGs. The research community has already identified the need for a more streamlined process for developing serious games. Most of the examples found in literature focus on this issue, while not necessarily SOA-based, decoupling the content of the SG from the underlying gaming software is a way of facilitating the extensibility of SGs and to support domain experts in the creation of content, which can then happen independently of the development of the game itself [Bellotti, 2009]. The ideas expressed in literature, and described in the following of this section, demonstrate that serious game development is going in the direction of modularization and compositionality.

The MetaVals Serious Game, for example, a game for practicing basic finance concepts, consists of a modular database and an independent graphic interface, with a management interface that facilitates configuring the game to different contexts [Popescu, 2008]. Authoring platforms also aim to reduce the complexity of game development. The eAdventure game platform aims to serve as an authoring platform for educational point-and-click adventure games, executing games defined in a specialized markup language [Moreno-Ger, 2007]. The authoring tool Puzzle-it divides the process of developing games into content authoring and core engine development, making it possible for instructors to create content for the games via the authoring tool without needing to be concerned about engine behind the games [Pranantha, 2012]. One significant step to allow for reusability in game implementations has already been taken with the advent of game engines, in 1997 was first introduced by Quake and marked the advent of the game-independent development approach [Lewis, 2002], [Petridis, 2012]. Game engines are collections of modules of simulation code that do not directly specify game logic, behaviour or game environment, and consequently can be re-used in different game projects [BinSubaih, 2008]. However, differently from the as-a-service approach, the games based on an engine are dependent on the selected engine, re-proposing the same issue.

When it comes to the actual usage of SOA in SGs, the examples available are very few. While the game itself has not been developed, a Service-Oriented Architecture was the approach of choice for an envisioned gaming platform based on mobile augmented reality (MARL). In this system, on-demand location-based instruction would be delivered through a head-mount display by a virtual instructor. In this architecture, the complete MARL game service would be composed by subsystems that would provide visual, human computer interface, and training services, allowing for the lower level objects to be encapsulated by the higher-level interfaces, making it easier for improvements in the algorithms to be incorporated into the service [Doswell, 2007]. One of the most interesting examples of SOA architecture for game-based education, the Rashi Intelligent Tutoring System teaches human anatomy through a problem-based environment. Rashi is built as a web service architecture that supports on-demand requests for small chunks of specific knowledge, instead of requests for an entire case specification at once, giving developers' flexibility to develop of lightweight inquiry tutors that run efficiently over the web [Floryan, 2011]. On top of the same existing service structure for the original (2D) inquiry system, the researchers built a 3D game in which the student is a doctor who must diagnose a patient in a virtual hospital. The GameTel project [Perez-Rodriguez, 2012] aimed to develop an open source software system for designing, developing, enacting, and assessing games and educational simulations adapted to the student skills and preferences. Flexibility was in the core of the effort, and the platform was being developed to be composed of different interconnected modules, which allow for integrating and communicating with the games and simulations, and to be executed in different platforms, formats, and devices. In the proposed architecture, the central component of the platform is exposed a Web Service, so that it remains independent of the access technology employed by users.

The as-a-service approach

In the future, a new generation of SGs will be able to provide compelling adventures set in highly realistic and information-rich environments, where quests/investigations can be solicited through competition and collaboration. This should lead to higher-order thinking, supporting strategic thinking, interpretative analysis, problem solving, planning and hypotheses verification. Exploiting the huge amount of digitally recorded data, learner assessment will be accurate along several dimensions and in real time, enabling immediate and formative feedback. This represents a significant complement with respect to the current educational offer (see Fig. 7).

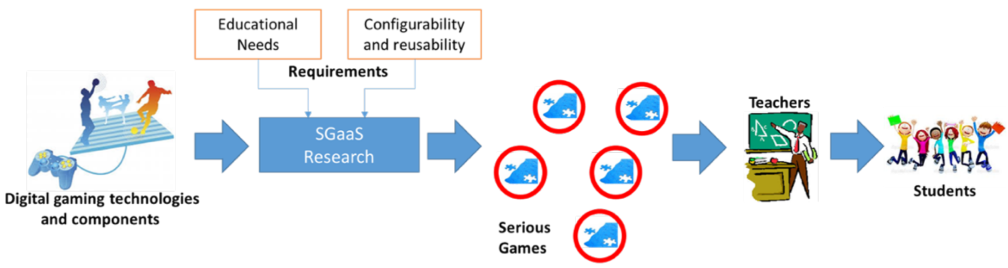

Fig. 7 Adapting digital gaming technologies and components to educational needs in order to be used to implement Serious Games

Implementing this vision will require a change in paradigm for SG development and deployment, targeting scalability, specialization and reusability. A comprehensive set of services (like the ones provided by the SGDE developed in this thesis) will be available in a cloud, for efficient and effective development of SGs, featuring extensive interoperability. These services will constitute the basic bricks for SG developers, providing functionalities (e.g., emergent narrative, virtual characters, interaction systems, assets, learning assessment analytics, natural language dialogue management, virtual characters' emotion management, etc.), that are useful in several different SGs (see Fig. 8).

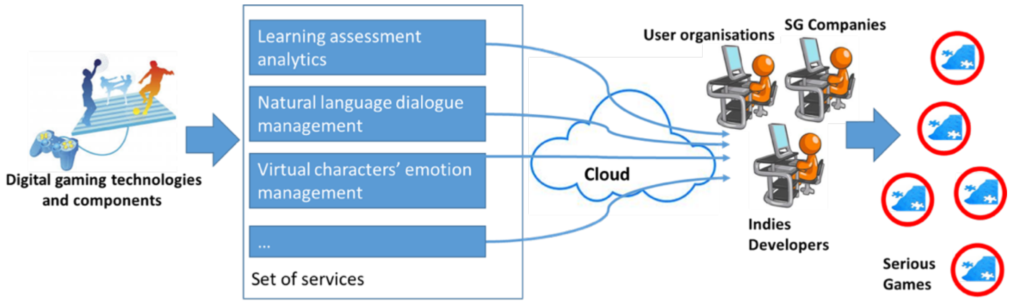

Fig. 8 The set of services available in the cloud to SG companies, indie developers and user organizations

Exploiting the Service Oriented Architecture (SOA) paradigm, these services will be available to SG development companies at lower costs than if the companies had to develop and maintain their own basic components. Beside cost reduction, this economy of scale (i.e., the same service used in several different third party SGs) will support reliability (each component will be tested in several different games) and quality enhancement (service developers will develop specialized services and continuously improve their quality). By building atop of such service bricks, SG companies will be able focus their resources on the added value of their own games (e.g., the plot, the contents, the pedagogical approach).

The proposed approach will also extend the paradigm of SG development. Professional developers, in fact, will be able to define different game templates assembling various services. Through a highly usable authoring tool like the XML format of the SGDE tool, educators will be able to choose such templates and creating new games by setting parameters and inserting their own contents (see Fig. 9). This will allow teachers to develop specialized games tailored to their own goals, such as supporting a school trip or teaching an episode of local history.

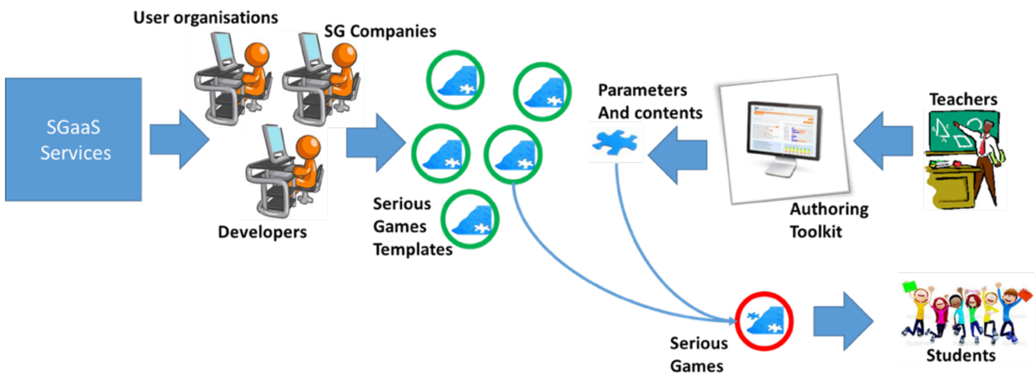

Fig. 9 The authoring tool for educators

The complete vision

SGs are still substantially based on game engines. However, game engines can automatically connect to one or more catalogues of SG-services in the cloud. Each catalogue contains a variety of services, that are organized and presented in a well-established taxonomy and appropriately described according to meta-tags that concern both pedagogical (e.g., expected educational benefits, target users, type of provided user assessment, etc.) and technical (e.g., how to programmatically connect to the service, what the pre- and post-conditions are, etc.) features. Browsing the catalogue, the SG developer organizations can choose the most suited services to meet their needs. The services are configurable by developers setting parameters for customized use. For instance, the matching module allows the developer (game designer) to specify the metrics/rules for similarity assessment. Services are seamlessly linked at runtime by the company's SG code, through the game engine. The services can run either at the service developer site or on the SGAAS platform. The cloud-based platform allows efficient execution and provision of meta-services, such as collection of information about service execution and overall SG and user profiling. This information provides very useful feedback to service developers, who are able to improve their existing services and to think of new ones, and to game developers, who can know what the most effective and useful services are.

Developers can also prepare and deploy SG templates (possibly targeting different specific application domains and users, such as math for kids, business simulations, historical events, etc.). Such templates combine different services and run on the SGDE platform (or on the template developer's site). Teachers and trainers can develop their own games by simply selecting such predefined templates, setting their parameters and inserting their contents.

The overall improvement in the SG development process allows efficiently bringing to the teachers and trainers' hands (i.e., very close to the end-users) a variety of high quality new SGs at low costs, creating a critical mass, thus increasing the SG sector's appeal also by the big digital gaming companies.

The idea is to establish, in the long run, a SGDE catalogue and the cloud-based execution platform as a catalyzer for boosting the SG market, by creating a meeting point between demand and offer of components for SG development. The components are at various level of granularity, from the low level basic services for virtual world asset generation (useful to SG developer companies) to the higher-level templates (useful for teachers that want to create/customize their own games or even let their students to develop exercise SGs). This is similar to the Apple iTunes and similar stores model on the consumer market, but specifically targeted at the development of SGs. We got inspired from a consumer market approach since we believe that facilitating the developer task and increasing their basis will be a key driver for overall market extension. In fact, the current bottleneck is represented not by the schools/industries (where awareness of the educational/training potential of SGs is reasonably established), but by the availability of really effective SGs, that can be deployed in class or at home at reasonable costs and with clearly defined and measurable pedagogical objectives.

The actual business model for the catalogue and the platform will have to be defined after the SGDE will be completely deployed and after the scope of the present research work. However, it is fundamental that these tools satisfy a need. Developers, at least initially, will be able to deploy services on the catalogue/platform for free and may get revenues from service users (e.g., SG developer companies) on a pay-per use basis. The cloud manager, hosting the catalogue/platform, will benefit from the number of visitors on the website and from the offer of meta-services, concerning the use of the services, and the overall user and SG-use profiling. Also, royalties on the exploitation of the single hosted/advertised services may be paid.

Business benefits are thus foreseen for all the actors in the value chain. Technological companies will exploit the emergent SG market by offering to third parties services that stem from existing technologies in the entertainment gaming area, such as procedural model generation, or telemetry. Research organizations will have a new distribution channel where they can deploy their research artefacts (also legacy components, since they may be wrapped as services, thus easily accessible by a much wider audience through the SG market-facilitation tools). They will also be able to design ever more advanced services, also exploiting data about service usage made available through the execution platform. Start-up companies, stemming from research labs and works, may also be generated, focusing on the commercial target.

The goal of SGDE is to become in the future a platform offering highly relevant SG component services and the related development and management tools.

We believe that implementing this approach will enable creation of the market that is necessary to concretely satisfy the need of teachers and trainers to provide students with new, effective and appealing tools for learning and training.

The as-a-service platform

From a technological point of view, the enlarged SGDE idea will set up a platform for development and deployment of serious games (SGs) relying on the Service Oriented Architecture (SOA) paradigm, as depicted in Fig. 10

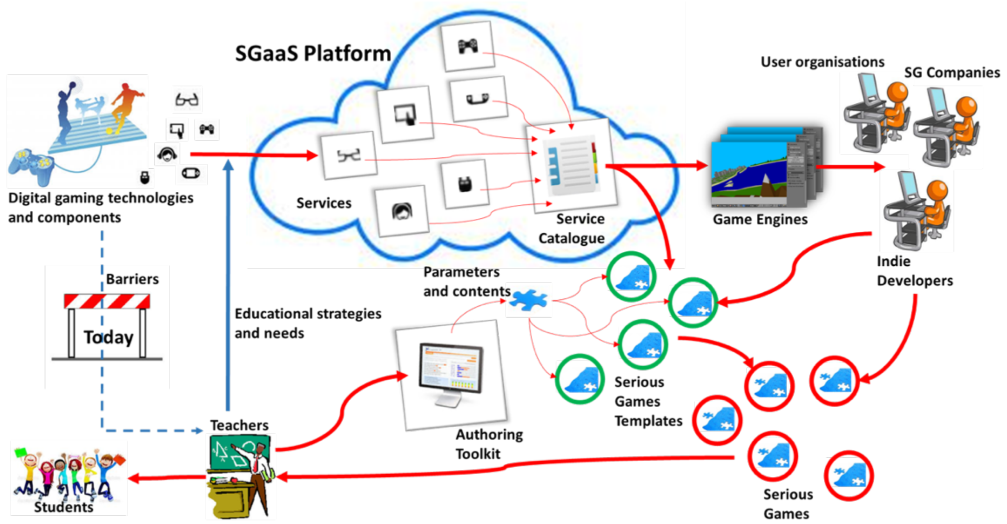

Fig. 10 The SGDE service/oriented platform

The current development process is expensive in terms of time and resources, especially considering the modules supporting user learning, that have to deal with the complexity of the human cognitive processes. Furthermore, the SG market size is not comparable with that of entertainment games and the SG production budgets are usually very limited, while the end-user expectations are high, because they are familiar with AAA videogames.

The vision is to allow the availability of a set of highly reliable, scalable, configurable and interoperable services that will provide the high-quality foundation functionalities for a new generation of SGs. Such SGs will be built as a set of services that will be deployed in the cloud (following the “as a service” paradigm). The services will be developed by companies that target such specific modules focusing on performance and educational value. Availability of such configurable and composable services will allow game designers and (for simpler games) pedagogical and domain experts to focus on the specific added value of their games, reusing high quality and highly reliable and tested components (the services).

Some of these components (e.g., about user profiling and game data mining) are already available in the gaming industry and can be wrapped or adapted. So, the traditional digital game industry will have the possibility of using a new outlet in which to provide their technologies to the educational game sector that will benefit from availability of such modules, exploiting economies of scale. Moreover, existing game engines will be upgraded in order to allow developers to directly include the new services.

Every service will be accompanied by configuration modules, so that SGs will result from a customized execution of the services, according to the actual educational targets of the specific SG developer.

An SGDE service catalogue will provide a list of services made available to customers by game technology companies. Each service within the catalogue typically includes: a description/categorization of the service, supporting services, subscription costs (if any), how to request the service and how its delivery is fulfilled. Any SG developer company will be able to go to the catalogue website to search for a specific service (e.g. game-play management, emergent narrative services, profiling and assessment, asset services, etc.), see description and details before seamlessly binding it from their own SG code.

An online authoring tool will be developed as well, in order to help the game design activity. The tool will also allow domain experts and educators (e.g. teachers, also with no programming skills) to visually compose homogeneous classes of games by customizing pre-defined templates with specific own contents.

Barriers and obstacles

It is possible that the as-a-service approach can be seen just as a set of technologies for exposing, running, and managing functionalities: nothing more than web services and middleware. The critical (wrong) point in this reasoning is that it confuses the technology (e.g. web services) with the whole development process that will be implemented in the enlarged SGDE. The SGDE development chain is enabled by the web-services, but aims at decoupling the implementation of game functionalities from their consumption, in order to allow developers to focus on the real added value of their contribution (e.g., the plot, the game metaphor, a compelling mechanic for teaching a mathematical concept in a game), while reusing (and customizing) high level components for the other elements of the game.

A successful approach adoption requires a cultural shift in the way SGs are designed and developed. The service-oriented idea of loosely coupling software components requires a shift from traditional, waterfall styles of development (featuring the consequential steps of design-build-test-deployment-management) to iterative agile approaches. The loose coupling leads to a heterogeneous approach to functionality access, that reduces dependence on single-vendor APIs. The change may be difficult for existing SGs developers and companies.

In a service-based SG (as any other software product), security and performance issues shift from the game boundaries to the federation of all the services included in the game. This can be a barrier to the adoption of services due to the uncertainty about the security of data (who knows the data of my users?) and the provided performance level (what can I do if my game become slow because a service does not respond promptly?). It is thus necessary to pay attention in the design of the service contract to cover all aspects related to safety and the quality of service, and the service catalogue/platform must support high levels of service.

Another potential obstacle for the acceptance of the proposed approach can be the common analogy of comparing service-oriented approaches with LEGO. The metaphor is based on the observation that complex games can be abstracted as assemblies of simple blocks. Although this can be a good introduction to the idea, it has to be stressed that the software pieces (i.e., services) can be customized, enhanced and composed with much more flexibility than the LEGO pieces.

Chapter 4

The Sand-Box Serious Game model (SBSG)

Serious games present a promising opportunity for learning, but the genre still lacks methodologies and tools for efficient and low-cost production, particularly for teacher and domain experts. This chapter gives an authoring framework that aims to provide structured support, from content design to final implementation. In particular, we have abstracted a conceptual mode (SandBox Serious Game) which relies on a generalization of task-based learning theory, introduced in the previous chapter. The model invites players to perform cognitive tasks contextually while exploring information-rich virtual environments. The model defines games that are set in realistic virtual worlds enriched with embedded educational tasks, which we have implemented as mini-games. This approach simplifies the authoring work, which can easily be supported by visual authoring tools for ontology-based 3D modelling and implementation tasks, thus allowing an approach similar to the mind-maps concept. We propose a top-down methodology for content preparation, starting from a global-level analysis down to the single points of interest and associated tasks, which are instances of simple predefined mini-game/quiz typologies. We provide examples and discuss criteria for selecting task typologies according to the authors' cognitive targets.

SBSG Concept

The SBSGs concept [Squire 2008; Bellotti et al. 2010a] relies on research on cognitive processing (how information is stored, retrieved, and represented [Atkinson and Shiffrin 1968; Tulving 1972]) that stresses the importance of helping students to develop well-connected knowledge structures representing relationships among facts and concepts. When the knowledge structure for a topic is well connected, new information is more readily acquired because the cognitive load is low [Greitzer et al. 2007].

Thus, when developing interactive applications that aim at knowledge acquisition and skill development, it is necessary to design a proper cognitive-supporting structure. A paradigm can be abstracted, via the analysis of effective SBSGs, which tends to provide players with a suitable knowledge structure for the targeted topic. In rough terms, the model consists of

- a concrete spatial organization - the virtual world (VW) of the game – where knowledge is distributed;
- tasks that are spread in the VW. Tasks are simple activities that embody units of knowledge which can be discovered by the user and played in order to construct meaning, build lasting memories and/or deepen understanding [Bellotti et al. 2010b].

An extensive use of tasks relies on task-based learning (TBL) pedagogical theory [Willis 1996; Willis and Willis 1996], which stresses the importance of concrete, focused activities to develop knowledge and skills. Tasks are activities characterized by the ability to engage the learner's interest; a primary focus on meaning; a need for completion; an outcome in terms of which success is judged; and a clear relationship with real-world activities [Willis 1996].

TBL concerns language instruction [Ellis 2003], but we generalize the term to videogame tasks, which are activities that provide the same features but are not restricted to the language domain.

In our research, we have implemented an SBSG platform (presented in the next chapter) that allows multiplayer online gaming in 3D environments and interaction with players' avatars and virtual characters. In our model, tasks can be annotated pedagogically. Authors annotate tasks by adding semantic-relevant meta-information about their types, content, supported user-learning styles, and so on. This allows decoupling the tasks, which can be reused in different SGs from the definition of their delivery strategy in a specific SG, which is specified by the SG designer (who is not the content/task author), and automatically managed by a runtime engine.

Tasks are implemented as mini-games that focus the player's attention on a particular item that he or she may find during his virtual exploration in the game environment. Sample tasks are inspired by well-known simple game models, such as "Puzzle", "Memory", and "Find-The-Wrong-Details".

The idea, in fact, is that they should be made immediately playable, so that the player can focus on the content rather than on learning how to play. In order to provide consistent and homogeneous interaction modalities (which can be quickly and easily learned by the player and then used several times), we have defined a library of task templates. Every task in the VW is an instance of one such template (typology). This approach also simplifies authoring work and makes it more efficient, allowing reuse of tasks in different SGs, thanks to the availability of an authoring toolkit which allows easy instantiation from the templates.

The Virtual World

The SBSG paradigm (i.e., a player's exploration of a virtual environment and the performance of localized tasks) looks promising for the educational domain, since a user can discover and interact with artefacts (e.g. implant in a farm or pieces of art in a museum) while exploring a contextual world in an adventure-like fashion.

In particular, the paradigm seems to meet two major requirements. First, it implements a 3D reconstruction of a real settings (plant, museum) for education goals within an interactive environment (the serious game). This is a process that requires a careful trade-off between the photorealism of 3D models, which is necessary to provide a highly impressive, culturally correct, and meaningful experience, and the need for interactive real-time online exploration. Second, complex VWs are costly to implement, both for modelling the 3D structure itself and for taking pictures, rectifying and equalizing them, and composing the final textures to be managed by the graphic engine at runtime.

In a highly interactive system, such as a 3D exploration/game, displaying the details of the reconstructed environment is not fundamental, as there the player moves rapidly. However, in the case of a SG, the player (playing as a sort of detective) has to examine details, where relevant. In order to meet the requirements stated above, we will exploit past results developed from our research team [Bellotti, 2011] about the reconstruction design of each covered place, according to the following high-level rules.

- The 3D model is completely geo-referenced. The ground is taken from a local 2D vector map, so placement of items (buildings in a city or instrument in a farm) in the model is precise. This also allows exploiting synergies with open geographic information systems (GIS) APIs (e.g. Google Maps and Microsoft Virtual Earth), which are now commonly exploited in combination with Web technologies to build location-based services.

- In each covered area, a few points-of-interest (POIs) are implemented (Fig. 11). These POIs are rigorously reconstructed with a high level of detail. We use this approach for education meaningful items, such as industrial instrumentation in the FoodGame example, described in Chapter 5.
- The textures for all the other palaces are built via a statistical ontology-based algorithm. Since several zones within an area are typically characterized by relatively homogeneous colours/details.

Fig. 11 Shapshot from the FoodGame

The idea of exploiting a statistical description of the architectural parameters (e.g., types of windows, roofs, number of floors, are organized in an ontology defined on the basis of existing architectural grammars such as that of Stiny) and create the building textures by statistically assembling architectural components representative of that area is described in [Bellotti et al. 2011]

With this approach, the effort to cover extended areas is reasonably manageable and the reconstructed environment allows users live experiences which are similar to an actual exploration, where a user typically has the feeling of being in a precise place but does not usually perceive/remember the details of each distinct items.

Instead, the POIs that are expected to be the subjects of a more exacting analysis by players are reconstructed at a high level of detail and with their own specific textures (i.e., not statistically defined). Currently, there are two major approaches for modelling special POIs (e.g. monuments, equipment). The first one consists in the actual polygonal reconstruction of the monument, and is mostly used for cultural reconstructions. The resulting model can be very precise, but achieving high quality usually requires defining a huge number of polygons, which are heavy to load at runtime, and such a model takes time to build [Patias 2007]. The second approach is the billboard, which was developed to represent natural trees in videogames. This solution is mostly used in real-time videogames, which cannot afford long loading (and model development) times, and consists in attaching a photo of the monument to a flat plane that is continuously rotated by the system so that it is always in the player's frontal view. This limits the realism and the quality of the implementation.

In order to overcome these drawbacks, we have tried to apply a procedure based on an enhancement of the billboard approach, consisting in the use of multiple textures (photos of the POI) which are displayed at different viewing angles. This keeps the simplicity of implementing the POIas a flat plane, but allows seeing different pictures from different viewing angles, instead of always looking at the same picture, independently of the angle of view. For each POI, it is necessary to provide a set of N pictures taken with the camera's line of sight perpendicular to the POI and spaced every (360/N) degrees on the equator line (Fig. 12). A preliminary test showed that the minimum number of pictures to give a meaningful idea of the monument is N=4, corresponding to the 4 main directions. The POI (in the example a monument) can be thought of as surrounded by a sphere and the digital camera placed in N positions on the sphere's equator. The lenses of the camera are directed towards the centre of the sphere. In this way, we keep the development of 3D models for monuments within a short timeframe and allow virtual world explorers to have a reasonable view. The approach represents a use of a standard videogame technique (multiple texture bill-boarding) as a simple and efficient technique for authors to easily produce usable content.

Fig. 12 Snapshot from a POI designed with the multiple-billboard technique

Task (mini-game) Typologies

This section gives an introduction to the task typologies that we have implemented in the platform as software templates. The task typologies are easy and most of them are adapted from "paper and pencil" quizzes or simple, popular computer games. For this reason, we call them mini-games as well, even if the concept is more general. We broadly divide them in three categories, according to the cognitive skills they mostly involve (Tab. 1).

Category	Description
Observation tasks	These tasks privilege sight for investigating and exploring the local environment. In general, these games tend to exploit "knowledge in the world" in order to develop cognition [Dickey 2003; Ducheneaut et al. 2006]. They aim to stimulate spatial processing skills. Such skills are important in cognitive development since they allow creation of meaning by manipulating visual images [Pillay et al. 1999; Kahana et al. 1999].
Reflection tasks	These tasks tend to favour reflection, analysis of questions and possible answers considering the clues available in the neighbourhood and concepts learned previously during the game
Arcade tasks	These tasks stimulate similar skills as observation games do. Their specificity lies in the animated graphics and engaging interaction, which helps create a convincing and pleasant experience. They stimulate fantasy and evoke images and atmospheres that can be used to convey educational messages which are easily memorized by players.

Tab. 1 Task Template Categories

The Treasure Hunt Model

The developed paradigm —built atop of the Unity3D game engine—provides a flexible framework which can be used to implement a number of SG applications with different types of content.

When developing an SG, besides possessing content (virtual environments, tasks), it is necessary to identify the game context and plot in order to make it appealing. Considering the nature of the proposed platform, which favours creation of tasks and their contextualization (placement) at suitable positions in a 3D environment, we thought of a treasure hunt game plot, since it would promote discovery in a real context (e.g. a city, a farm), with ever-new content available to players without need to change the software. Instances of tasks can, in fact, be easily produced by domain experts and used as challenges at appropriate stages of the treasure hunt.

The plot of the treasure hunt game is simple and schematic; but it represents a format that is scalable and flexible in terms of content, which could be developed cost-effectively and could also be used by third parties and in a user generated content (UGC) context. Teachers/experts could also control the tasks available for a game by simply specifying those available for their topic of interest.

Also, a simple, easy to understand structure—coupled with task created as instances of templates whose interaction modalities can be easily learned once by a player and applied in several different cases—poses little cognitive overload for the player, who can effectively focus his attention on the content and context.

There is a risk that the player may have a “clunky” experience, since the author is not required to specify a complete narrative. However, some sandbox-like games are successful in the market where the player builds his own narrative experience by interacting with contextualized situations and mini-adventures during exploration of a wide geographic environment (e.g., Oblivion, Grand Theft Auto, etc.). The game author specifies such situations and the game’s general reward/competition mechanisms, not the details of the plot.

Chapter 5

The Serious Games Development Environment (SGDE)

Creating a videogame involves a series of development steps performed by different experts, or teams. The steps include:

- **Game design**, consisting in the ideation of the mechanics, structures and rules of a game.
- **Level design**, design of a game map where all the interactive and static elements are positioned in the game world (scene).
- **Game programming**, including display of the scene (which is usually automatically performed by game engines such as Unity 3D, Unreal Engine 4, Crytek, Lumberyard, etc.), user interaction management, event specification and management, and logic of the game.
- **Game art design**, which is the artistic process where all the 2D and 3D elements of the game are developed, through modelling tools such as 3ds Max, Maya, Blender, Softimage, Cinema 4D, etc., and photo-editing tools, such as Photoshop, GIMP, etc.
- **Audio production**, where music and sound effects are created.

Literature analysis

New methodologies are needed in order to support design of games able to effectively combine fun and learning [Greitzer, 2007], covering all the above-mentioned points. A literature review shows the following main approaches to the problem:

- [Ushaw, 2015] describes how developers with extensive experience in the entertainment video game industry approach the creation of rehabilitative games. They present a number of design and implementation practices that bring a heightened sense of engagement and replay value to games for patients.
- [Callele, 2005] argues that most video games development failures are due to improper requirements engineering, especially because of the associated costs [Boehm, 2001]. They conclude that new methods are needed to support the transition from game design document through formal requirements and specifications.
- [Salazar, 2012] proposes enhancing a game design document from the software engineering requirements perspective.
- [Furuichi, 2014] proposes a SG design process consisting of eight phases: user needs definition, planning, user needs analysis, system architecture, software design, coding and test, integration and qualification test, deployment and field test, evaluation.
- [Ibáñez, 2009] proposes a development methodology based on the concept of Knowledge Centered Approach. The methodology features seven steps: creation of a knowledge base, knowledge characterization, connection of pedagogical and game scenario, creation of the cognitive model, deduction of learning activities, game genre definition, integration of knowledge into the game.

- [Preston, 2014] presents a scalable and repeatable process to focus participant creativity through constrained design to rapidly prototype games that have the potential for behavioural change intent and knowledge retention among players.
- SeGAE is a SG authoring environment providing authors a set of editors to adapt a SG to their specific pedagogical needs [Yessad, 2010].

Service Oriented Architecture approaches promise to make SG development faster and easier, also enhancing modularity and flexibility. [Carvalho, 2015a] presents a case study of a simple SG exploiting a web-service for player's formative assessment. The activity theory-based model for serious games analysis and conceptual design (ATMSG) method has been defined in order to support a systematic and detailed representation of educational SGs, depicting the ways that game elements are connected to each other throughout the game, and how these elements contribute to the achievement of the desired pedagogical goals [Carvalho, 2015b]. [Carvalho, 2015c] studied the application of the ATMSG method for identifying the most suited SG components that could be implemented as services in the cloud.

In recent years, development of video games has been hugely facilitated and enhanced by the use of game engines. Such tools eliminate all the programming effort needed for the graphic and the physics, leaving to the game programmer "just" the implementation of the specific game rules and level design. In the specific field of SGs, IGER is built upon the Panda3D game engine, and provides features tailored to rehabilitation such as a virtual therapist easily pluggable in the game [Pirovano, 2013]. [Tong, 2015] have shown that game engines can be used to develop serious games for cognitive assessment, cost effectively and without loss of predictive validity with respect to a purpose-built game. The next consequential step is represented by plug-ins that provide higher-level abstractions, for instance for dialogue/conversation management (e.g., [Shah, 2016; Mori, 2013]).

The framework proposed in this thesis is positioned in this point of the game development workflow, as it allows an automatic management of the events and of the player choices. The module is suited only to investigation games, where players have to search for clues, select the most promising ones, annotate facts, face trials (typically implemented as mini-games) and finally identify the final solution. Thus, the framework is not a universal solution, but the concept itself is general, and similar modules may be designed for other formats/typologies of games and SGs as well.

SGDE Architecture

The SGDE architecture is composed of several modules: the investigator model descriptor (an XML-based format to specify POIs and tasks), a set of mini-games types (in order to instantiate tasks) and the parser module (a game engine plugin able to run the information contained in the descriptor).

The supported game model

Based on the requirements coming from the analysis of SG types (see chapter 2 and 3), we have developed the SGSB game model, where the player has to explore a 3D virtual environment representing a city, region, natural area, factory, etc. In the environment, the player has to perform a quest/investigation, either hunting for damages/failures or facing trials and performing tasks such as mini-games in competition/cooperation with others players [Bellotti, 2010; Pranantha, 2012; Bellotti, 2009].

The SGSB [Bellotti, 2012] represents a model that can fit in several different contexts (e.g. exploration of a city's cultural heritage, of an industrial plant and its machinery, of human bodies [Kelly, 2007] or of the Oceans [Parker, 2007]).

The most didactically-relevant places in the quest environment are called points of interest (POIs). The player has to visit the POIs, play the corresponding tasks and/or collect clues. The tasks are usually implemented as mini games. POIs can be represented by a large variety of things ranging from monuments or historical buildings to pieces of machinery of a factory.

Based on our experience (see chapter 3) and state of the art analysis (particularly Hudlicka, 2009; Dormann, 2008; Jepp, 2010), we identified a set of requirements for the SGSG category of educational SGs. The main requirements are the following:

- Support to exploration of a virtual environment where the player can perform meaningful educational activities.
- Possibility of inserting in the scene point of interests (POIs) containing objects to be investigated or tasks to be performed.
- Possibility of describing the context (e.g., story and rules) in which the player acts and of the possible issues to face.
- Possibility of inserting in the scene explanations about actions a player may take.
- Possibility of inserting in the scene dialogues based on a tree hierarchy scheme through the interaction with non-player characters.
- Possibility of inserting in the scene help texts for players to familiarize with the game.
- Possibility of exploiting audio contents.
- Separation between data and code.

Such requirements have led us to the definition of the proposed module as a key factor for speeding up the development time of SGSB, or, more generally, of SGs including an investigation mechanic characterized as it follows.

The players have to face a challenge inside a virtual world. In order to achieve the goal, which is presented at the beginning of the game, the players have to explore a 3D virtual world where a set of POIs are placed in relevant positions. A POI may contain an object to be investigated or a task (e.g., a mini-game) to be performed in order to get more information about the place. If the player finds the final solution to the stated problem, he wins, otherwise has to try again and again in the exploration. A game may involve different plots in different sessions. At each game session, the plot to be followed in the session is randomly selected by the system. During the exploration, the player can collaborate or compete with others players by chatting with them and the score can take into account the performance of all players.

The first component of the SGDE architecture is a template for game authors to textually describe the challenge, the solution, and the POIs to be placed in the virtual world. This configuration file is interpreted by a game engine module, as described in the next section.

The investigation model descriptor

The investigation model descriptor proposed in this thesis is a plug-in for game application environments, typically game engines, aimed at facilitating the development of an SG. A game developer is required to describe the content of the game in a file, namely, the investigation instance descriptor, that is interpreted at game-loading time by a JavaScript module running atop a game engine. The module is responsible for fetching all the referred contents and create the game objects necessary to manage the correct execution of the game (Fig. 13). While the concept is general, the JavaScript module is currently implemented for the Unity 3D engine only.

Thus – provided that the SG model supported by the proposed descriptor is suited to the designer's goal – a game production can focus on the content and the graphics, without having to write code for managing the common structure and the mechanics of the model.

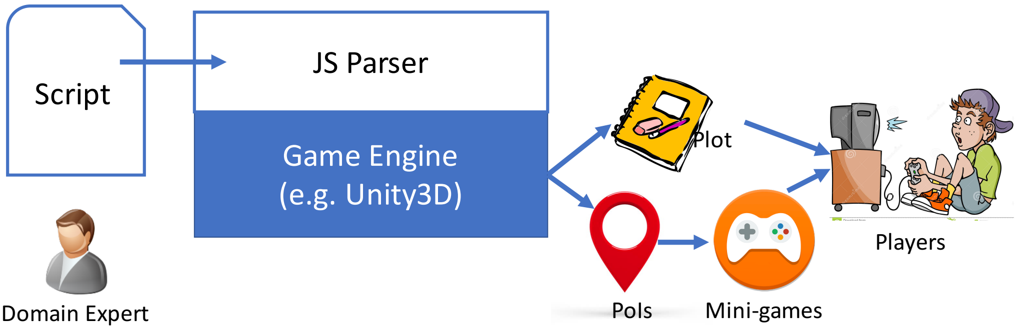

Fig. 13 High level scheme of the system

As shown in previous figure the description file (script) is structured according to a template describing POIs to be placed in the 3D world. The descriptor file includes a point-of-interest element, inside which the author can define the POI and its contents. Each POI can contain either an object or a task, typically a mini-game.

Mini-games are particularly suited to invite a player to perform an activity focusing on one or more aspects in the POI. Through each mini-game experience, a player may discover and collect information that could be useful to solve the final quiz/challenge.

Mini-games can be of different types such as “manuscript”, “puzzle”, “couples”, “image comprehension”, “contextualized questions”, “visual quiz”, “quiz”, “wrong details”, “missing details”, “right place”. Next sub-section describes in detail the various mini-game typologies, considering the cultural heritage application domain.

As an example, Fig. 14 shows a piece of XML code defining a mini-game of type “couple”, in which the player has to match items in two different sets. As an example, the “context” element provides a reference to an ontology to support semantic web.

```
<POI id=[the unique GUID identifier of the PoI]>
  <name>[A mnemonic name for the PoI]</name>
  <description>[A short sentence</description>
  <minigame id=[unique ID of the mini-game] type= “couple”>
    <name>[A mnemonic name for the minigame]</name>
    <instructions>Choose matching elements</instructions>
    <images>
      <image id=“1” side=“left”>img1.png</image>
       <image id=“2” side=“right”>img4.png</image>
       <image id=“3” side=“right”>img5.png</image>
    </images>
    <connections>
      <connection starimg=“1” endimg=“2” />
    </connections>
    <context>
      <ref> http://dbpedia.org/page/definition</ref>
    </context>
  </minigame>
</poi>
```

Fig. 14 Piece of XML code describing a minigame of type “couple” inside a PoI

POIs are particularly suited to invite a player to analyse an item in order to understand if the item is the main subject of the quest stated at the beginning of the game. Here the idea is that the player can analyse several different POIs (i.e., objects) in the virtual world, take notes and finally find the one which best fits the game’s quest. Each object is characterized by a set of parameters, according to its nature, with different values. If the player recognizes that some of these parameters are not within the proper value range, he can annotate the situation, and finally decide what is the most relevant object (either in positive or in negative) for the initially specified game challenge. As shown in Fig. 15 a POI can contain a set of parameters without a mini-game.

```
<POIid=[GUID]>
  <name>[Name]</name>
  <description>[Description]</description>
  <images>
    <!--> ... <-->
  </images>
  <parameters>
    <parameter id="1" name=[Name] type="continuous">
      <description>[Description]</description>
      <visualization_style>Dial</visualization_style>
      <range>
        <min>0.2</min>
        <max>2.5</max>
      </range>
      <unit>[Unit]</unit>
    </parameter>
  </parameters>
  <questions>
    <question id="1">
      <why>[Question]</why>
      <difficulty>3</difficulty>
```

```
      <answer id="1" correct="0">[Answer 1]</answer>
      <answer id="2" correct="1">[Answer 2]</answer>
      <answer id="3" correct="0">[Answer 3]</answer>
       <answer id="4" correct="0">[Answer 4]</answer>
    </question>
  </questions>
</poi>
```

Fig. 15 Piece of XML code defining a POI with description

In the XML template, for each parameter, the game designer can provide the range within which the parameter's values are valid. In a typical SG, most of the parameters are set correctly, and the player has to discover which parameters are set incorrectly. The XML template provides a list of "suspect" elements, that are items containing one or more parameters whose values are not within the range. When a game is loaded, all the parameters in all the POIs are set randomly to values within the right ranges. However, such correct values are overridden, with values directly set by the game author, for those POIs and those parameters that are in the suspect list (see Fig. 16).

```
<suspect id=[GUID] target="0" game_id="1">
  <poi_id>[POIGUID]</poi_id>
  <likelihood>5</likelihood>
  <parameters_of_interest>
    <parameter_id target="0" value="0">2</parameter_id>
    <parameter_id target="0" value="1">3</parameter_id>
  </parameters_of_interest>
</suspect>
```

Fig. 16 Piece of XML code defining a suspect featuring two parameters.

Each suspect item is characterized by the following attributes: id, target and game_id. The attribute target is Boolean. If it is set to 0, it means that, even though not all its parameters are correct, this POI is not the main subject of the quest. Alternatively, the 1 value indicates that this POI is the actual target of the search.

As there may be more than one game plots in a game, the plot for the current session is randomly selected at the beginning of the session. Thus, several targets may be set to 1, but only one for each reference game_id.

The plot of the game is presented to the players through the expedient of a newspaper article that appears just after the game is launched. The players are invited to read the article in order to become aware of the challenge they are going to face. The template provides a "game_plot" element through which the authors of a game can define one or more variants of the game plot (Fig. 17).

The plots are characterized by the following children elements:

(a) start_title
(b) start_text
(c) end_title_good
(d) end_text_good
(e) end_title_wrong
(f) end_text_wrong

(a) and (b) provide respectively a short and a detailed description of the initial situation and of the problem to solve. (c) and (d) provide a short and a detailed description of a positive conclusion of a game. (e) and (f) provide a short and a detailed description of a negative conclusion of a game.

```
<game_plots date="dynamic" name="The Game News">
  <game_plot id="1">
    <start_title>[Title text]</start_title>
    <start_text>[Start text]</start_text>
    <end_title_right>[End title (wins)]</end_title_right>
    <end_text_right>[End text (wins)]</end_text_right>
    <end_title_wrong>[End title (loose)</end_title_wrong>
  <end_text_wrong>[End text (loose)]</end_text_wrong>
  </game_plot>
</game_plots>
```

Fig. 17 Description of a game's plots.

The module also allows developers to set the game's soundtrack through the "soundtrack" element. The "globals" element provides the information needed by a player at the beginning of a game session (Fig. 18).

```
<globals>
  <title>[Title text]</title>
  <description>[Description text]</description>
  <soundtrack mute="on">
    <sound level="menu">[file menu]</sound>
    <sound level="newspaper"> [file newspaper]</sound>
    <sound level="all"> [file all]</sound>
  </soundtrack>
</globals>
```

Fig. 18 The template allows the selection of music contents.

Non-Player Characters (NPC) are typically present in the scene. Through the "questions" element, a dialog is enabled between the player and the NPC who is closest to the PoI. The goal of the dialogue is to test and/or enrich the player's knowledge on the item presented at the PoI.

Minigames

The task described in the context of the SBSG paradigm (Chapter 3) are developed in a set of templates. Tab. 2 lists the task templates we have implemented.

Name	Description	Cognitive aspects
Manuscript (Reflection)	The player must insert missing words in a text document. He can choose the possible alternatives from a dropdown menu. In a slightly more difficult case, the player has to first identify wrong words in the text and, once identified, select the alternative.	Reasoning about text and language; evaluation of alternatives.
Image comprehension (Observation)	The player must answer a list of questions related to an image (e.g., who are the people in the picture? What is the symbolic meaning of a detail/the whole picture?). The multiple answer questions appear beside the image.	Observational skills; understanding images; reflection; analysis of questions and search for possible answers; iconographic analysis (training the player in the interpretation of a picture and its details).
Contextualized questions about a picture	The player must explore an image with a wand tool. In some areas, the wand pop-ups a question related to underlying image detail and the player must	Observation skills; understanding images; attention to detail; critical reasoning; speed of

(Observation, Reflection)	answer it among multiple choices in a short time.	reflexes; analysis of icons.
Quiz, VisualQuiz (Reflection)	This is a simple multiple-choice list of questions. The question is generally tied to its location in the virtual world. Samples include historical quizzes, guessing games, local dialect/language quizzes. A version with images instead of written questions is also available (VisualQuiz). The user has to click on the right answer in the text or image.	Reflection; analysis of questions and possible answers considering available clues and concepts previously learned; evaluation of alternatives; memory; critical reasoning.
Wrong or missing details (Observation)	The player must detect all details that have been deleted or added to an image. The user clicks on them until all are found (or he/she pushes the exit button). Immediate feedback is provided.	Analysis of the image; observation of and focus on details; iconographic analysis.
RightPlace (Reflection, Observation)	The player must move (by dragging-and-dropping) several icons in their right places over an image representing a geographic or conceptual map. The icons are initially placed in a column to the right of the map. Placements can be overridden by dropping a new icon in that place. Feedback is provided at the end of the game.	Observation; critical reasoning; matching; map comprehension; mental map generation.
Puzzle (Observation)	The player must compose an image by dragging its rectangular pieces which initially appear randomly distributed, and dropping them in the target position. Feedback is only	Observation skills; memory; ability to identify geometrical patterns; attention on colours and shapes.

	provided at the end. Help is available (once a piece is positioned in its right place). The player may have seen the relevant item during his exploration or may be playing just in front of the 3D model.	
Couples (Reflection, Observation)	The player must match the items in the right column with those on the left by pointing and clicking. A connection can be deleted (by clicking on one of its two images). Feedback is provided only at the end (right, wrong, and missing connections). Help is available (one right connection is displayed).	Observation; critical reasoning; matching; image comprehension.
CatchIt! (Arcade)	On a 2D cartoon background, a non-player "launcher" character throws objects from a tower/balcony. The player moves a "catcher" character (with the left and right key arrows), who has to catch the "right" objects and avoid the "wrong" ones.	Promptness of reaction; observation.

Tab. 2 Description of Task Templates

A fundamental feature of task templates is that they are parametric. Every task instance is described by a configuration file that specifies the values of the instance's parameters. The configuration file is prepared by the pedagogical or domain-expert author. This allows educational experts who are not familiar with programming to create new task instances. Parameters involve content (i.e., text, images, difficulty levels, etc.); timing (of questions and answers); and multimedia display (i.e., buttons, sounds, fonts, colours, etc.).

Some important parameters concern learning mechanisms, and are used in computing a score, which is key for competition and game level advancement. Thus, the way in which rewards and penalties are computed is fundamental in encouraging or discouraging some player behaviours. Typical parameters we use for task score computation are the time elapsed, number of help requests, and the number of steps/moves to arrive at the solution. In fact, these are the factors we usually consider when evaluating a student. Since an author may reward precision (e.g., minimal number of moves in solving a puzzle game) more than speed in accomplishing a task, in order to invite players to an accurate rather than fast analysis of the topic, we let the author set the overall score as a weighted sum of the scores obtained by measuring a player's performance in terms of time and accuracy, as we see in the example in Fig. 19.

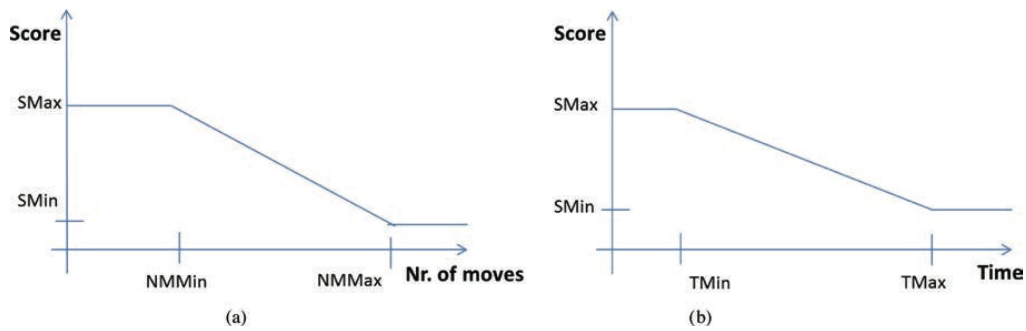

Fig. 19 Parameters for score computation in terms of accuracy (a) and timing performance (b).

Some parameters can be managed automatically by the runtime system, in order to increase the usability range of the game, thus enhancing the possibility of its reuse [Bellotti et al. 2009b]. For instance, the difficulty level of a task could be dynamically adjusted. In a puzzle game, the number of pieces is decided dynamically based on the level of the player. Similarly, quizzes can reduce the number of possible answers presented to the player.

Tab. 3 shows the main parameters of the Puzzle task template. The number of rows and columns can be changed automatically by the runtime system for the sake of adaptivity.

Parameter	Description
Number of rows	Number of rows into which the image is divided in the game.
Number of columns	Number of rows into which the image is divided in the game.
Max number helps	Maximum number of helps that a player can request (or is provided automatically). The help consists in the fact that the system puts one piece in its right place.
Help timeout	Timeout after which a help is provided automatically.
Help cost	Score value detracted from the final score for each help given.
Deadline	Maximum playtime length.
Accuracy assessment weight (Aaw)	The final score is the weighted sum for accuracy assessment and time performance assessment. An author (teacher) may reward accuracy more than completion speed, penalizing a "trial and error" approach by the player and inviting him or her to a more reflective behaviour.
Time assessment weight (Taw)	The relative weight (expressed as a percentage) of time performance assessment. The sum of Aaw and Taw is 100%

Tab. 3 Parameters for the Puzzle task template

With a potentially large number of embeddable tasks, it becomes important to define strategies for providing single users with the most suitable tasks during exploration of the virtual world. This requires defining a model of the task, a model of the user, and a model of the target learning strategy. In order to allow for this, tasks can be annotated with metadata that specifies the pedagogical features of the task and the POI to which it is related [Bellotti et al. 2010a]. Typical task metadata includes types, contents, supported user learning styles, and positions; while user data includes learning styles, task type preferences, content preferences, and performance [Bellotti et al. 2009c].

This allows an artificial intelligence (AI)-based runtime management system, namely, the experience engine (EE), to deliver tasks dynamically during a game session to support the acquisition of personalized knowledge. For more information about the Experience Engine, please refer to [Bellotti et al. 2009b]. In particular, the EE's AI learns an appropriate task- scheduling policy whose requirements are specified by the author, exploiting the user and task models. For instance, a teacher could prepare a game with tasks that stress the weakest learning style of each player. With this approach, the domain-expert author focuses on characterizing tasks, on the expected learning curve, and on user needs, while the task sequencing, which takes the real user profile and runtime interaction into account, is delegated to the EE.

This paradigm of preparing a large database of reusable tasks is particularly useful for an efficient production of games.

The Parser Module

Video games usually consist of a complex structure, involving graphic elements, models, animations and scripts defining the game mechanics. For this reason, the Parser module has been developed to be capable of handling several aspects, creating an abstraction layer over them, and making them controllable by the user (i.e., an SG developer) through the XML template described on the previous section. By filling the template, an author provides instructions to the game engine to easily manage the following lower level items:

- The global variables of the game
- The choice of the game plot and of the corresponding solution
- The distribution of data in the different POIs
- The management of suspected parameters
- The graphic visualization of all the POI information with the creation of custom graphic elements
- The translation of the user interface into different natural languages supported
- Management of graphic skins
- Management of the music
- Management of the solution of the game (one solution for every plot)
- Generation of the help of the game
- Parsing of the XML file containing the parameters of the game

The Parser module has been implemented in Unity 3D at the moment (but can be ported also on different engines) by creating six prefabs. Prefabs are containers that can contain one or more game objects (the elements making up the scenes), each one of which can have one or more scripts. Three of them (namely, Settings, PoIInfo and GamePlots) are to be deployed in every game instance, while three (HelpBox, MainCamera, Player) are optional. Here follows a short description of the plug-in's prefabs:

Settings is the prefab used to set the elements of the game (such as the link to the XML script file from which the game data are loaded by the plug-in, the natural languages in which the interface of the game is available).

PoIInfo are prefabs corresponding one to one to POIs, i.e., they encode the POIinformation and manage their behaviour. A PoIInfo includes two triggers, that are areas where access by a player is detected, so that an event is triggered upon player's entrance and the player can start interacting with the task or parameters present in the PoI. The first trigger allows detecting proximity to the

PoI, while the second supports proper visualization, i.e., activation only when the avatar is looking at the targeted object. The values for each trigger are set visually by the developer by using the Unity 3D developer interface.

GamePlots is the prefab managing the different possible plots in a game, as discussed previously.

Player represents the default player. In Unity 3D, the player prefab includes both the avatar and the scripts to manage his behaviour. SG developers can replace the default player to implement a more specific behaviour.

MainCamera is the prefab representing the camera following the player in the game. This prefab can be replaced with a custom camera.

HelpBox aims at explaining to the player which interactions can be performed by using the joystick, the mouse or the keyboard.

By reading the description script, the Parser creates the prefabs. The Parser has to be placed by the developer in the Unity 3D game scene. Correct positioning is crucial for the PoIinfo, Player and MainCamera prefabs, while any position is suited for the other three prefabs.

It is worth noting that the module exploits specific features of the Unity 3D engine. Porting to other game engines is feasible, even if the implementation may not be straightforward.

Chapter 6

Games examples

In the following chapter, we demonstrate the potential of the SGDE tool describing some SGs developed using the framework.

Can’s Crime Example

The first example uses only the investigator model descriptor and the Parser. Its name is “Can's Crime” and aims at teaching the industrial processes of a factory to Logistic Engineering students, by exploiting the example of a factory for sardines boxing. “Can's Crime” has been developed within the European project ISEKI_Food 4 [ISEKY, 2016], that intends to innovate the food chain by improving education in Food Studies.

When the game starts, a newspaper page is shown, which explains the plot of the game (Fig. 20). In this case, the newspaper reports on a case of food poisoning caused by sardines boxed in cans.

The Game News

50¢

CITY FINAL | FRIDAY MARCH 11, 2016 | VOL. 32 NO.10

50 People ill from Eating Canned Sardines

The sardine factory in our city is identified as a source of major foodborne illness. Inspectors will arrive tomorrow to find the cause.

Yesterday, over 50 adults and children became sick after visiting a local fund raising event. All concerned patients admitted to hospital were complaining of a variety of illnesses, such as vomiting, diarrhea, itching of the skin, nausea, drop in blood pressure, and rash on the upper body. Most of them were experiencing tingling or burning sensation in or around the mouth or throat. After investigator interviewed some of the patients and found out that all of them had eaten one food in common during the lunch – sardines. The symptoms suggest that the sardines were contaminated with high levels of histamine. Samples have been sent to the regional laboratory for tests. In the meantime investigators are planning to fly to the factory where sardines were canned. They will interview the factory staff and conduct on-site inspection to determine if the plant improperly processed the product that caused histamine poisoning at the fund raising event.

Twinkleton Caught on Video with Known Terror Suspects

Abu Al Gahrib recorded accepting container suspected of containing C4

FBI agents, CIA operatives, and Homeland Security personnel have been following the notorious accountant Schmendrick Twinkletons for nearly seven years in hopes of finding

DFL - GOP Runners Face Off in National Televised Debate

Presidential hopefuls will field questions from a

Fig. 20 In a "Can's Crime" session, the player has to investigate a case of intoxication due to the consumption of sardines boxed in cans.

An investigator has been appointed with the mission of discovering the cause of the Poisoning. The player has thus to explore the sardine canning factory and find out what has gone wrong with the sardine boxing process. After arriving at the factory, the investigator meets the director, who provides him augmented reality glasses and protective clothes for visiting the factory, for health reasons. After talking to the director, the investigator enters the factory and starts his journey through the pieces of machinery of the factory. The factory areas are visited in an order corresponding to the various steps of the food boxing process. Every time the player approaches a machine, all the information related to the corresponding element is shown (Fig 9), also including the current value of the parameters and the acceptable value range. If a parameter's value is unacceptable, the player can record it in a notepad. At the end of the game, the investigator is asked which parameter, among those recorded in the notepad, is the cause of the malfunctioning of the plant. If the investigator answers are correct, the game is successfully completed, otherwise the player is invited to try again.

Name	Description	Parameter name	Ranges	Is suspect?	Is solution?
Chlorination of Water	Chlorination of water is carried out to ensure that water is microbiologically safe.	Free Chlorine	0.2-2.5ppm	No. Random value in the correct range	No
		Total Chlorine	0.2-2.5ppm	No. Random value in the correct range	No
		Bacteria	0/1 (correct 0)	No. Value set to 0	No
Preparation of sauces (PS)	Various ingredients are mixed based on the required type of sauce mix.	Organoleptic characteristics	0/1 (correct 0)	Yes. Value set to 1	No
		Defects	0/1 (correct 0)	Yes. Value set to 1	Yes

Tab. 4 Examples of POIs in “Can's Crime” game

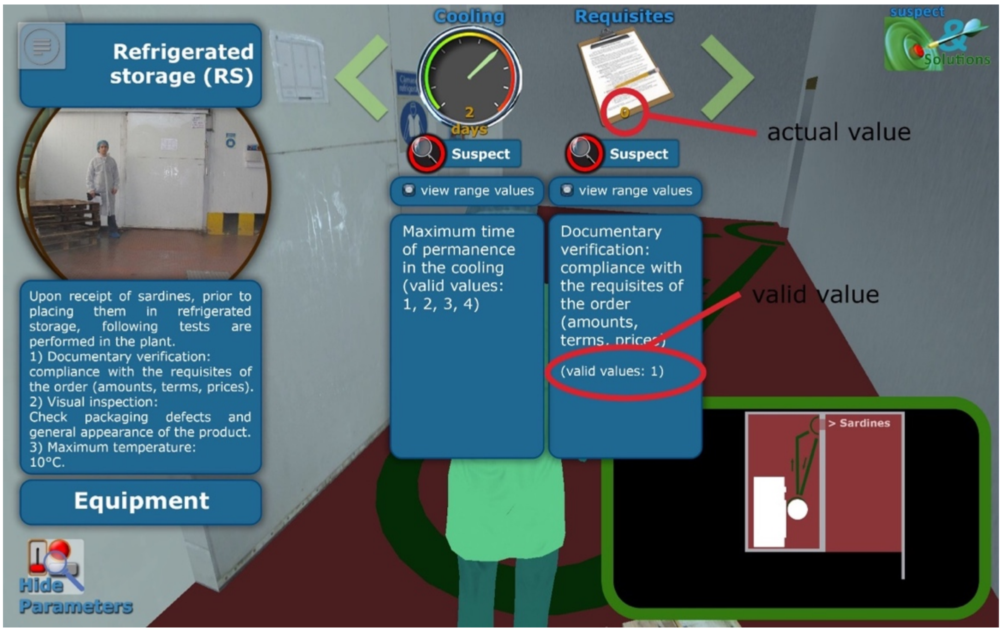

Fig. 21 In the Refrigerated storage step, the actual value is different from the valid value. Thus, this item could be the cause of the problem.

The “Can's Crime” game features 19 POIs placed in significant places inside the factory, each one representing a step of the food canning process (e.g., chlorination of water, salt storage, boxes of fresh sardines, steam heating, can exterior cleaning, can storage, etc.). The Tab. 4 provides the details of some of such steps.

Draweva

Today people in organizations are working in what are called “invisible silos”: they only are aware of their own targets. At the same time, they often are not aware about others and miss out the opportunity to create synergies, supporting others to achieve their targets or to reach out to others to ask for help.

The goal of the Draweva game is to create awareness for this behaviour, so that employees in organizations will focus more on synergies with others and collaborate beyond their own area of responsibility. In Fig. 22 a screenshot from the game 3D setting.

Fig. 22 A screenshot from the Draweva game

The game is played simultaneously by three teams of each seven players with the major goal of killing a monster: Draweva (Fig. 23).

Fig. 23 The Draweva monster (an example of PoI)

This requires killing him in a special way and before a certain time. Each team is lead to believe to fight its own individual creature. There is a Vampire, a Werewolf and a Dragon. But actually, it is one creature composed of the three different ones, situated in a caste in the centre of the game map (Fig. 24).

Fig. 24 The final Castle (another PoI)

There are seven routes to the castle. Each team puts one member on every road, so that there are three members from different teams, faced with the same task, on each road. Every team member has his own task according to the road he is on. There is the Weapon specialist, Sourcing specialist, Logistical specialist, Safety specialist, Creature specialist, Bodyguard and the Team leader. The positions are all connected and interdependent to each other:

- The weapon specialist has to find a weapon to kill Draweva.
- The sourcing specialist has to find a special additive for the weapon, to make it more lethal.
- The logistical specialist has to find an opportunity to fly in the special additive from abroad.
- The creature specialist has to find a way to call allies to help fighting Draweva.

- The bodyguard needs to find attack methods to weaken Draweva.
- The safety specialist has to find ways to protect the bodyguard from Draweva.
- The team leader has to lead the team in terms of decisions about strategy and item purchases.

The game is departed in five phases (each phase of approximatively 15 minutes) in which the players are faced with different tasks that simulate regular situations in an international company. In each phase, the players have to do nearly the same tasks according to their team and position. Except of the team leader, who has to overlook the actions of his team and make decisions based on the information he gets from his team members. His main task is to manage the limited budget and the time. The phases for the other six players are the following:

- Phase 1 (collecting information): the player has to collect information according to his specialty by posing questions to different Non-Player Characters (NPCs). At the end of this phase the player should give his team leader some general information.
- Phase 2 (empowerment): the player has to ask a certain team member for information he can't get himself. As he will get also requests from others, he has to collect information in order to answer correctly.
- Phase 3 (challenge with rivals): the players will get to a point in the virtual world which is only passable once independent on how many players pass at the same time. If a player arrives before the others and passes, he later finds out that he has to return to help the others cross. This task takes a lot of time.
- Phase 4 (synergies): the players arrive in front of a castle. But to get in they have to pay guardians by mining diamonds that can be found

nearby. There is the possibility for the teams to share diamonds and pay only one guardian, in order to save a lot of time.

- Phase 5 (killing): the players confront with the Draweva monster while realizing that it is just one creature. They have to use the items the team leader bought earlier based on the information of his team to kill Draweva.

Chapter 7

Experimental results

In this chapter, we present some preliminary results about the current potentiality of the SGDE. Together with Chapter 6 about the description of some game developed with SGDE, this chapter represents the experimental evidence of the approach.

In the development of a new game, the use of the SGDE allow designers to produce games with a versatile structure, quite easy to maintain and extend. One important goal achieved is the high degree of separation between data and code. The content of the game (or, more generally, the part related to the investigation), in fact, is stored in the descriptor file, which can be easily edited also by non-programmers. This is particularly important for SG design, where authors need to be domain experts in the target fields, such as history, art, natural science, etc.

In order to have a quantitative assessment of the benefits obtainable through SGDE, we designed a pilot aiming to assess usability and gain in development time, which is the main goal of the present work, as high development costs are a major limitation for the spread of educationally valuable SGs.

Experiment description

Five people (4 PhD and 1 Post-doc; 2 of them are Italians, 2 Indians and 1 Tunisian) participated in the pilot. One of them is a humanistic domain expert with no programming experience, the other four come from an ICT Engineering department, with good programming expertise. None of them had working experience with a 3D modelling tool.

The pilot took place in a morning in our laboratory. The participants were required to develop a copy of a reduced version of "Can's Crime" example, consisting of three scenes: an initial scene introducing the problem to solve, a gaming scene with 10 POIs, and a final scene where the result of the game is provided.

Two test conductors spent around 20 minutes explaining to the participants how the SGDE works, giving them a pre-filled descriptor file as an example. Test users were introduced to the Unity 3D environment, which was installed on their PC. Then, they were given all the needed graphic elements (the 3D models constituting the virtual environment). The target game was verbally described, but not shown to the test users. Finally, they were asked to develop the game using the available material and, possibly, without asking information to the test conductors. They were assigned no time limits. During the test, it happened that only one question was asked to a conductor, about how to correctly position the triggers in the environment so to make the POI lie on the ground.

When all the test users completed the operation, the test conductors checked that all the tasks were accomplished correctly. The final result was assessed compliant with the specification according to the judgment of the two test conductors.

Results

The realization times are reported in tables below.

UserID	Programming Experience	XML file composition	Prefab and trigger positioning	Total development time
1	✓	20	32	52
2	✓	40	35	75
3	✓	23	50	73
4	✓	36	75	111
5	✕	28	80	108
Average		29,4	54,4	83,8

Tab. 5 Time (mins) taken by users to develop an investigation game instance

Step	Detail	Time (weeks)
Design of module interfaces and of data structure	Definition and grouping of the functionalities and variables to be implemented	3
POI data management	Implementation of the functions needed to insert (e.g., getting them from a configuration file) and manage data in the POIs	6
GUI items for the display of POI information	Library of GUI items to allow the display and animation of information (e.g., dials, switches, scales) (e.g. arrow rotates in dial display, or switch management, etc.)	8
Translation of the interface into different languages	Multilingual approach for the UI items since the beginning of the project	1
Multi-language UX	Multilingual approach for the UI items since the beginning of the project	1
Event management	Functions managing the events of the various UI components	2
Management of the game solutions	Functions managing the list of possible solutions for increasing playability	1
Help management	Functions for the script managing the game help	1
Total		23

Tab. 6 Development time of Can's Crime, from scratch, using Unity 3D

We divide the time to fill the XML descriptor file from the time needed to position the prefabs (and associated triggers) in the 3D environment.

Discussion

Results show that the development time is up to 111 minutes, with an average value of 83,8. In subsequent informal tests, we also noticed that using the SGDE multiple times can bring the development time down to around 45 minutes. The person with no programming experience needed a slightly longer time to complete the positioning task, but eventually succeeded, without issues. This result represents a major reduction of time with respect to a development from scratch that, based on our working experience, we estimate in around 5 months, as shown in table below. Of course, the time for developing the 3D graphics is not considered in the comparison, as it must be spent in both cases.

Also, the amount of code to be written decreases significantly from about 4,000 lines (C# code needed for the management modules and for the configuration of POIs and plots) to about 30 XML lines to configure each POI and plot.

After the exercise, participants were asked to report the difficulties met, in order to assess usability. According to the responses, most issues were found in correctly positioning the POIs in the 3D space, which is substantially related to the lack of experience in using a 3D modelling software. Also, some minor difficulties have been noticed when users had to fill the XML template, that could be easily overcome through a graphic user interface (GUI) form. The form would make the editing work more comfortable, and prevent mistakes such as accidental deletion of parts and tags, forgetting filling some parts, etc. The test conductors highlight that all the users correctly understood the meaning and the role of all the different prefabs, and which ones had to be instantiated multiple times and which only once. All users correctly performed the link between the XML script and the Setting prefab as well.

The size of the test is limited and cannot provide any statistical significance. More tests are necessary for a clearer assessment. However, the experiment allowed us to confirm the validity of the approach, that we argue could be extended to other types of games as well.

Chapter 8

Conclusions

The goal of this research has been the design of a tool for enhancing the development process of Sand-Box Serious Games. The developed SGDE allows an easy implementation and deployment of a game through which players can get and/or test specific knowledge about an environment through a challenging quest. Information about the game is inserted in a descriptor file that is interpreted and managed by a game-engine JavaScript plug-in. The module is now implemented for Unity3D, but could be ported to other engines as well. The SGDE has been used in the production of “Can’s Crime”, a 3D SG for exploring a manufacturing industrial plant, and, subsequently, of “Draweva”, a SG developed to teach leadership skills to managers.

The proposed tool allows a significant reduction of development time and amount of code to be written, also supporting non-programmers. Moreover, the code is only a semi-structured description of the SG instance settings and contents, and can be written with little difficulty by non-programmers.

The positioning of the POIs in the game scene is more complicated for users not experts with 3D modelling tools. We are considering the development of a visual authoring tool in order to further simplify the task. The authoring tool may include also a form for an author to explicitly indicate content and learning objectives of each PoI. The descriptor file allows a flexible and straightforward management, upgrade and maintenance of the game's contents. The structure is completely modular, so that new types of mini games/tasks can be seamlessly added.

Of course, the benefits are limited to a specific investigation mechanic. The concept of identifying a suitable SG model and of creating a tool managing the set-up and execution of the format’s features and functionalities is general, and can be applied to different types of game genres and pedagogical goals. This allows high development efficiency, but also implies a clear limitation in flexibility, as the degrees of freedom for game design are limited to the different 3D models usable and the different configuration parameters settable by an author in the descriptor files. However, the prefabs of the tool could be used also as parts of more complex SGs, requiring a specific effort of game designers and developers. In general, identification of common sets of functionalities sharable among different applications is in line with the Service Oriented Architecture design approach, where programs are built up as mashes of cloud services. In particular, we have envisaged a possible approach to modify the future of SG design by exploiting the possibility of the as-a-service paradigm.

We have conducted also a limited test (no statistically significant in order to confirm the validity of the approach. In the future, more tests are necessary for a clearer assessment.

We believe that the next steps of the research in the field could go in two main directions. One is the extension of the format at a higher level, allowing authors to describe more complex plots joining the various POIs, tasks and objects available in the environment. On the other hand, it would be interesting to support adaptivity by allowing mini-games and POIs to adapt their difficulty level and/or other features according to the actual level of the player.

References

[Aalst, 2007] Aalst, W. M. V. D., Beisiegel, M., Hee, K. M. V., Konig, D., Stahl, C., 2007. A SOA-based architecture framework. International Journal of Business Process Integration and Management 2 (2), 91.

[Abt, 1970] Abt C., Serious Games, New York, Viking Press, 1970.

[Alfieri, 2008] Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R., Does discovery-based instruction enhance learning?, Journal Of Educational Psychology, 103(1), 2008, 1-18

[Angehrn, 2009] Angehrn A., Maxwell K., Luccini M., Rajola F., Designing Effective Collaboration, Learning and Innovation Systems for Education Professionals, International Journal of Knowledge and Learning (IJKL), Vol. 5 No. 2, 2009.

[Antoniou, 2010] Antoniou, a. And lepouras, G. 2010. Modeling visitors' profiles: Adaptation for museum learning technologies. ACM J. Comput. Cultural Heritage 3, 2, 1–19.

[Ashfield, 2010] S. Ashfield, C. Jarvis, J. Kaduk, Serious Games for Geographical Field Skills: An Exploration, vs-games, in: International Conference on Games and Virtual Worlds for Serious Applications, 2010.

[Atkinson, 1968] Atkinson, r. C. And shiffrin, R. M. 1968. Human memory: A proposed system and its control processes. In The Psychology of Learning and Motivation

[Aylett, 2009] R. Aylett, N. Vannini, E. Andre, A. Paiva, S. Enz, L. Hall, But that was in another country: agents and intercultural empathy, in AAMAS '09: Proc. Of The 8th International Conference on Autonomous Agents and Multiagent System, Richland, SC, 2009.

[Azadegan, 2012] A. Azadegan, J. Riedel, Serious Games Integration in Companies: A Research and Application Framework, 12th IEEE International Conference on Advanced Learning Technologies, 2012

[Baalsrud Hauge, 2013] Baalsrud Hauge J., Bellotti F., Berta R., Carvalho M. B., De Gloria A., Lavagnino E., Nadolski R., Ott M., Field assessment of Serious

Games for Entrepreneurship in Higher Education, Journal of Convergence Information Technology , pp. 1-12, Volume8, Number13, August 2013

[Bachen, 2012] Bachen, C. M., Hernández-Ramos, P. F., & Raphael, C. (2012). Simulating REAL LIVES: Promoting global empathy and interest in learning through simulation games. Simulation & Gaming, 43(4) - See more at: http://www.scu.edu/profiles/?p=3433#sthash.WFuJ4kba.dpuf

[Backlund, 2013] P. Backlund, M. Hendrix, Educational games - Are they worth the effort? A literature survey of the effectiveness of serious games, in: Games and Virtual Worlds for Serious Applications (VS-GAMES), 2013 5th International Conference on, Sept. 2013, 11-13

[Bastos, 2012] Bastos N. P., Morán Sánchez-Cantón B., Hervello Costas I., ENTRExplorer: a Serious Game for Immersive Entrepreneurs, Atas do Encontro sobre Jogos e Mobile Learning. Braga: CIEd., 2012

[Bell, 2008] Bell, f., savin-baden, m., and ward, R. 2008. Editorial for the special issue on learning and teaching in immersive virtual worlds. ALT-J Res. Learn. Technol. 16, 3.

[Bellotti, 2008] Bellotti, F., Berta, R., De Gloria, A., Zappi, V., 2008. Exploring gaming mechanisms to enhance knowledge acquisition in virtual worlds. DIMEA '08. ACM Press, p. 77.

[Bellotti, 2009a] Bellotti, F., Berta, R., De Gloria, A., Primavera, L., 2009. Adaptive experience engine for serious games. Computational Intelligence and AI in Games, IEEE Transactions on 1 (4), 264–280.

[Bellotti, 2009b] F. Bellotti, R. Berta, A. De Gloria, L. Primavera, Adaptive Experience Engine for Serious Games, IEEE Transactions on Computational Intelligence and AI in Games, vol. 1, no. 4, 2009, 264-280

[Bellotti, 2010] F. Bellotti, R. Berta, A. De Gloria, Designing Effective Serious Games: Opportunities and Challenges for Research, International Journal of Emerging Technologies in Learning, vol. 5, 2010, 22-35

[Bellotti, 2011] F. Bellotti, R. Berta, A. De Gloria, A. Ozolina, Investigating the added value of interactivity and serious gaming for educational TV, Computers & Education, Vol. 57, No. 1, 2011, 1137-1148

[Bellotti, 2012] F. Bellotti, R. Berta, A. De Gloria, A. D'Ursi, V. Fiore, A Serious Game Model for Cultural Heritage, Journal on Computing and Cultural Heritage (JOCCH), Volume 5 Issue 4, December 2012, Article No. 17

[Bellotti, 2013] Bellotti F., Berta R., De Gloria A., Lavagnino E., Antonaci A., Dagnino F., Ott M., (2013a), "A Gamified Short Course for Promoting Entrepreneurship among ICT Engineering Students", Proceedings of IEEE

International Conference on Advanced Learning Technologies (ICALT) 2013, Bejing, China, July, 2013, ISBN 978-1-4673-1642-2, DOI 10.1109/ICALT.2013.1.

[Berta, 2013] Berta R., Bellotti F., De Gloria A., Pranantha D., Schatten C., "Electroencephalogram and Physiological Signal Analysis for Assessing Flow in Games", IEEE Transactions on Computational Intelligence and AI in Games, Vol. 5, No. 2, 567-578, 164-175, June 2013

[BinSubaih, 2008] BinSubaih, A., Maddock, S., 2008. Game Portability Using a Service-Oriented Approach. International Journal of Computer Games Technology 2008, 1–7.

[Boehm, 2001] B. Boehm and V. Basili, Software defect reduction top 10 list, IEEE Computer, vol. 34, no. 1, Jan. 2001, 135-137

[Bull, 2010] Bull, S., & Kay, J. (2010). Open learner models. In Advances in Intelligent Tutoring Systems (pp. 301-322). Springer Berlin Heidelberg.

[Callele, 2005] D. Callele, E. Neufeld, K. Schneider, Requirements Engineering and the Creative Process in the Video Game Industry, in: 13th IEEE International Conference on Requirements Engineering. La Sorbonne (France), 2005.

[Carvalho, 2015a] M.B. Carvalho, F. Bellotti, R. Berta, A. De Gloria, G. Gazzarata, Jun Hu, M. Kickmeiter-Rust, A case study on Service-Oriented Architecture for Serious Games, Entertainment Computing, volume 6, January 2015, 1-10.

[Carvalho, 2015b] M. B. Carvalho, F. Bellotti, R. Berta, A. De Gloria, C. Islas Sedano, J. Baalsrud Hauge, J. Hu, and M. Rauterberg, An activity theory-based model for serious games analysis and conceptual design, Computers & Education, Volume 87, September 2015, 166-181, http://dx.doi.org/10.1016/j.compedu.2015.03.023.

[Carvalho, 2015c] M. B. Carvalho, F. Bellotti, J. Hu, J. Baalsrud Hauge, R. Berta, A. De Gloria, and Matthias Rauterberg, Towards a service oriented architecture framework for educational serious games, in: 15th IEEE international conference on advanced learning technologies (ICALT2015), Hualien, Taiwan, 2015, 147-151. doi: 10.1109/ICALT.2015.145

[Chen, 2004] Chen M., and Johnson S., "Measuring flow in a computer game simulating a foreign language environment," 2004. Available online at: http://www.markdangerchen.net/pubs/flow_in_game_simulating_fle.pdf

[Chen, 2007] Chen J., "Flow in games (and everything else)," Commununications of the ACM 50, 4 (April 2007), 31-34

[Chi-Husiung, 2012] Chi-Husiung Liang, "Solving family communication problems between children and parents by using Mobile Serious Games," Interactive Collaborative Learning (ICL), 2012 15th International Conference on , vol., no., pp.1,6, 26-28 Sept. 2012

[Chiang, 2008] Chiang Y. T., Cheng C. Y., and Lin S. S. J., “The Effects of Digital Games on Undergraduate Players' Flow Experiences and Affect,” in proceedings of the Second IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL '08)

[Clark, 2003] Clark D., Learning by playing: can computer games and simulations support teaching and learning for post-16 learners in formal, workplace and informal learning contexts? Computer games in education and training. Presentation at LSDA seminar London, November 2003.

[Cole, 2012] Cole, S.W., Yoo, D.J., Knutson, B. (2012). Interactivity and Reward-Related Neural Activation During a Serious Videogame. PLoS ONE 7(3).

[Connolly, 2007] Connolly, T.M., Boyle, E.A., Stansfield, M.H., and Hainey, T., “The Potential of Online Games as a Collaborative Learning Environment”, Journal of Advanced Technology for Learning, 2007

[Csikszentmihalyi, 1990] Csikszentmihalyi M., Flow: The Psychology of Optimal Experience, New York: Harper & Row, 1990.

[Dale, 1969] Dale, E. 1969. Audiovisual Methods in Teaching, Dryden Press, New York.

[Daniel, 2012] Daniel, J. (2012). Making Sense of MOOCs: Musings in a Maze of Myth, Paradox and Possibility. Journal of Interactive Media in Education.

[De Freitas, 2009] De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., And Poulovassilis, A. 2009. Developing an evaluation methodology for immersive learning experiences in a virtual world. In Proceedings of the Conference in Games and Virtual Worlds for Serious Applications.

[De Grove, 2010] De Grove, F., Mechant, P., And Van Looy, J, 2010. Uncharted waters? Exploring experts’ opinions on the opportunities and limitations of serious games for foreign language learning. In Proceedings of the 3rd International Conference on Fun and Games.

[De Paolis, 2011] De Paolis, L. T., Aloisio, G., Celentano, M. G., Oliva, L., And Vecchio, P. 2011. Otranto in the Middle Ages. a serious game for the edutainment. Int. J. Inf. Edu. Technol. 1, 1.

[Deloitte, 2012] Deloitte, Technology Trends 2012 - Elevate IT for digital business, online: http://www.deloitte.com/view/en_US/us/Services/consulting/technology-consulting/49ec911905f25310VgnVCM3000001c56f00aRCRD.htm

[Dewey, 1933] Dewey, J., “How We Think”, Heath, New Yor, 1933

[Dickey, 2003] Dickey, M. D. 2003. Teaching in 3D: Pedagogical affordances and constr, aints of 3D virtual worlds for synchronous distance learning. Distance Edu. 24, 105–121.

[Djaouti, 2008] Djaouti D., Alvarez J., Jessel J.P., Methel G., Molinier P., "A Gameplay Definition through Videogame Classification", International Journal of Computer Game Technology, Hindawi Publishing Corporation, Quarter 1, 2008.

[Djaouti, 2011] Djaouti D., Alvarez J., Jessel JP, "Classifying Serious Games: The G/P/S Model" Patrick Felicia (ed), "Handbook of Research on Improving Learning and Motivation through Educational Games: Multidisciplinary Approaches", IGI Global, 2011.

[Dormann, 2008] C. Dormann, R. Biddle, Understanding game design for affective learning. in: Proceedings of the 2008 Conference on Future Play: Research, Play, Share, Toronto, Canada, November, 2008.

[Doswell, 2007] Doswell, J., Harmeyer, K., 2007. Extending the 'Serious Game' Boundary: Virtual Instructors in Mobile Mixed Reality Learning Games. In: DiGRA. pp. 524–529.

[Doucet, 2010] Doucet, L. And Srinivasan, V. 2010. Designing entertaining educational games using procedural rhetoric: A case study. In Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games,

[Ducheneaut, 2006] Ducheneaut, N., Yee, N., Nickell, E., And Moore, R. J. 2006. Alone together? Exploring the social dynamics of massively multiplayer online games. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.

[Duin, 2012] Duin, H., Cerinsek, G., Oliveira , M.Bedek, M., & Dolinsek, S. (2012). Using Behavioural Indicators to Assess Competences in a Sustainable Manufacturing Learning Scenario. International Conference on Advances in Production Management Systems, 24-26 September 2012, Rhodes, Greece.

[Economou, 1998] Economou, M. 1998. The evaluation of museum multimedia applications: lessons from research. Museum Manage. Curatorship 17, 1, 73–187.

[Egenfeldt-Nielsen, 2006] Egenfeldt-Nielsen,S, Overview of research on the educational use of videogames, Digital Kompetanse, 3(1), 2006.

[Ellis, 2003] Ellis, R. 2003. Task-Based Language Learning and Teaching. Oxford University Press, Oxford, UK.

[Falk Anderson, 2010] Falk Anderson, E., Mcloughlin, L., Liarokapis, F., Peters, C., Petridis, P., And De Freitas, S. 2010. Developing serious games for CH: A state-of-the-art review. Virtual Real. 14, 4, 255–275.

[Floryan, 2011] Floryan, M., Woolf, B. P., Jul. 2011. Optimizing the Performance of Educational Web Services. In: 2011 IEEE 11th International Conference on Advanced Learning Technologies. IEEE, pp. 399–400.

[Foni, 2010] Foni, A. E., Papagiannakis, G., And Magnenat-Thalmann, N. 2010. A taxonomy of visualization strategies for CH applications. ACM J. Comput. Cultural Heritage 3, 1.

[Furuichi, 2014] M. Furuichi, M. Aibara, K. Yanagisawa, Design and Implementation of Serious Games for Training and Education, in: 2014 UKACC International Conference on Control 9th -11th July 2014, Loughborough, UK.

[Gartner, 2013] Gartner, "Gartner Predicts Over 70 Percent of Global 2000 Organisations Will Have at Least One Gamified Application by 2014", press release, available online: http://www.gartner.com/it/page.jsp?id=1844115

[Gee, 2003] Gee J. P., What Video Games Have to Teach Us about Learning and Literacy, New York: Palgrave Macmillan, 2003.

[Göbel, 2010] S. Göbel, S. Hardy, Wendel, V. Mehm, R. Steinmetz, Serious Games for health: personalized exergames, in: Proceedings of the international conference on Multimedia (MM '10). ACM, New York, NY, USA, 2010.

[Greitzer, 2007] F.L. Greitzer, O.A. Kuchar, K. Huston, Cognitive Science Implications for Enhancing Training Effectiveness in a Serious Gaming Context, ACM J. Educational Resources in Computing, vol. 7, no. 3, August 2007.

[Hannig, 2012] Hannig A., Kuth N., Özman M., Jonas S., Spreckelsen C., eMedOffice: A web-based collaborative serious game for teaching optimal design of a medical practice, BMC Medical Education 2012, 12:104

[Hassan, 2012] Hassan, M., Hossain, M., Alamri, A., Hossain, M., Al-Qurishi, M., Aldukhayyil, Y., Ahmed, D. T., 2012. A cloud-based serious games framework for obesity. In: CMBAS-EH '12. ACM Press, New York.

[Heller, 2006] Heller, J., Albert, D., Kickmeier-Rust, M., & Kertz, M. (2006). Achievement Motivation, Performance Structure, and Adaptive Hypertext Learning. In M. Pivec (Ed.), Affective and Emotional Aspects of Human-Computer Interaction. Game-Based and Innovative Learning Approaches. IOS Press.

[Hoadley, 2004] Hoadley, C. M. (2004). Methodological alignment in design-based research.Educational psychologist, 39(4), 203-212.

[Hudlicka, 2009] E. Hudlicka, Affective game engines: motivation and requirements. in: Proceedings of the 4th international Conference on Foundations of Digital Games, Orlando, USA, April , 2009

[Hurwitz, 2007] Hurwitz, J., Bloor, R., Baroudi, C., Kaufman, M., 2007. Service Oriented Architecture For Dummies. –For dummies. Wiley.

[Ibáñez, 2009] B.C. Ibáñez, V. Boudier, J.M. Labat, Knowledge Management Approach to Support a Serious Game Development, in: 9th International Conference on Advanced Learning Technologies (ICALT). Riga, 2009.

[IDATE, 2012] IDATE Serious Games Market Report. http://www.idate.org/en/News/Serious-Games_643.html

[Islas Sedano, 2013] Islas Sedano, C., Carvalho, M.B.; Secco, N., Longstreet, C.S., "Collaborative and cooperative games: Facts and assumptions," Collaboration Technologies and Systems (CTS), 2013 International Conference on , vol., no., pp.370,376, 20-24 May 2013 doi: 10.1109/CTS.2013.6567257

[ISEKY, 2016] https://www.iseki-food4.eu/

[Janarthanan, 2012] V. Janarthanan, Serious Video Games: Games for Education and Health, in: 9th International Conference on Information Technology - New Generations, 2012

[Jarvis, 2009] Jarvis, S., de Freitas, S., Evaluation of a Serious Game to support Triage Training: In-game Feedback and its effect on Learning Transfer. Proceedings of 2009 IEEE Conference in Games and Virtual Worlds for Serious Applications, 2009

[Jepp, 2010] P. Jepp, M. Fradinho, J. M. Pereira, An Agent Framework for a Modular Serious Game, in: Proceedings of the 2010 Second international Conference on Games and Virtual Worlds For Serious Applications, March, 2010.

[Kelly, 2007] H. Kelly, K. Howell, E. Glinert, L. Holding, C. Swain, A. Burrowbridge, M. Roper, How to build serious games. Communications of ACM, vol. 50, no. 7, Jul. 2007, 44-49

[Kickmeier-Rust, 2007] Kickmeier-Rust, M. D., Peirce, N., Conlan, O., Schwarz, D., Verpoorten, D., & Albert, D. Immersive Digital Games: The Interfaces for Next-Generation E-Learning? In C. Stephanidis (Ed.), Universal Access in Human-Computer Interaction. Applications and Services (pp. 647-656). Lecture Notes in Computer Science, 4556/2007. Berlin: Springer, 2007.

[Kickmeier-Rust, 2009] Kickmeier-Rust, M. D. Talking digital educational games. In M. D. Kickmeier-Rust (Ed.), Proceedings of the 1st international open workshop on intelligent personalization and adaptation in digital educational games (pp. 55-66). October, 2009, Graz, Austria

[Kickmeier-Rust, 2011] Kickmeier-Rust, M. D., Mattheiss, E., & Albert, D. (2011). Experiences With an Approach to an Unobtrusive Assessment of Motivational States in Immersive, Narrative Learning Environments. ECGBL 2011, October 20-21, 2011, Athens, Greece.

[Kincaid, 2009] Kincaid, J.P., Westerlund, K.K., "Simulation in education and training," Proceedings of the 2009 Winter Simulation Conference (WSC), Dec. 2009.

[Kirkpatrick, 1998] Kirkpatrick, D. L., "Evaluating Training Programs: The Four Levels", Berrett-Koehler Publishers, Inc, San Francisco, 1998.

[Kirriemuir, 2004] Kirriemuir J., McFarlane A. Literature Review in Games and Learning Report 8: Futurelab Series, 2004, available online at: http://hal.archives-ouvertes.fr/docs/00/19/04/53/PDF/kirriemuir-j-2004-r8.pdf

[Kirschner, 2006] Kirschner, P.A., Sweller, J., Clark, R.E. "Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching". Educational Psychologist 41 (2): 75–86, 2006.

[Klopfer, 2009] Klopfer E, Osterweil S., and Salen K., Moving Learning Games Forward, Obstacles Opportunities & Openness, The Education Arcade, Massachusetts Institute of Technology, 2009, available online at: http://education.mit.edu/papers/MovingLearningGamesForward_EdArcade.pd f.

[Kolb, 1984] Kolb, D. A., “Experiential Learning”, Prentice Hall, New York, 1984

[Lewis, 2002] Lewis, M., Jacobson, J., 2002. Games engines in scientic research. Comm. of the ACM, 27–31.

[Liu, 2009] Liu C., Agrawal P., Sarkar N., and Chen S., “Dynamic difficulty adjustment in computer games through real-time anxiety-based affective feedback,” Int. J. Human-Comput. Interact., vol. 25, no. 6, pp. 506–529, Aug. 2009

[Lopes, 2011] Lopes R., Bidarra R., "Adaptivity Challenges in Games and Simulations: A Survey," Computational Intelligence and AI in Games, IEEE Transactions on , vol.3, no.2, pp.85-99, June 2011

[Ma, 2014] M. Ma, L. C. Jain, P. Anderson, Future Trends of Virtual, Augmented Reality, and Games for Health, in: Virtual, Augmented Reality and Serious Games for Healthcare 1, Volume 68 of the series Intelligent Systems Reference Library, Springer, 2014, 1-6

[Maritain, 1985] Maritain, J., La personne et le bien commun, (1947) trans. The Person and the Common Good, by John J. Fitzgerald, Notre Dame, IN: University of Notre Dame Press, 1985.

[Mayer, 2013] Mayer I., van Dierendonck D., van Ruijven T. and Wenzler I., Stealth Assessment of Teams in a Digital Game Environment, in Proc.s of Game and Learning Alliance, GaLA Conf 2013, Velizy Paris, Oct. 2013.

[Michael, 2006] Michael, D. & Chen, S., Serious games: Games that educate, train, and inform. Boston, MA.: Thomson Course Technology, 2006.

[Mitchell, 2004] Mitchell, A., & Savall-Smith, C. (2004). The use of computer and video games for learning. A review of the literature. The learning and skills development agency. London, p.57.

[Montessori, 1946] Montessori, M. Education for a New World. Madras, India: Kalakshetra Publications, 1946.

[Moreno-Ger, 2007] Moreno-Ger, P., Sierra, J. L., Mart´ınez-Ortiz, I., Fern´andez-Manj´on, B., 2007. A documental approach to adventure game development. Science of Computer Programming 67 (1), 3–31.

[Mori, 2013] D. Mori, R. Berta, A. De Gloria. V. Fiore, L. Magnani, An easy to author Dialogue Management System for Serious Games, ACM Journal on Computing and Cultural Heritage (JOCCH), Volume 6 Issue 2, May 2013

[Nonaka, 2000] Nonaka, I., Toyama, R. and Konno, N., “SECI, Ba, and leadership: a unified model of dynamic knowledge creation”. Long Range Planning, vol. 33, no.5, 2000

[O’ Broin, 2011] O’ Broin D., "Using a Criteria-Based User Model for Facilitating Flow in Serious Games," Third International Conference on Games and Virtual Worlds for Serious Applications, VS-Games 2011

[Oliveira, 2013] Oliveira, M., Cerinsek, G., Duin, H., Taisch, M., Serious gaming in manufacturing education, In M. Ma et al. (Eds.): Serious Games Development and Applications, SGDA 2013, LNCS 8101, pp. 130–144, 2013.

[Pannese, 2007] L. Pannese, M. Carlesi, Games and learning come together to maximize effectiveness: The challenge of bridging the gap, British Journal of Educational Technologies, vol. 38, issue 3, May 2007, 438-454

[Papastergiou, 2009] M. Papastergiou, Digital Game-Based Learning in high school Computer Science education: Impact on educational effectiveness and student motivation, Computers & Education, vol. 52, no. 1, Jan. 2009, 1–12

[Papazoglou, 2007] Papazoglou, M. P., Traverso, P., Dustdar, S., Leymann, F., 2007. Service-Oriented Computing: State of the Art and Research Challenges. Computer 40 (11), 38–45.

[Parker, 2005] J.R. Parker, S. Chan, J. Howell, OceanQuest: A University-Based Serious Game Project, in Proc. Digital Games Reseaech Association Conference (DiGRA 2005), Vancouver, BC, June 2005.

[Parsons, 2012] Parsons, D.; Petrova, K.; Hokyoung Ryu, "Mobile Gaming - A Serious Business!," Wireless, Mobile and Ubiquitous Technology in Education (WMUTE), 2012 IEEE Seventh International Conference on , vol., no., pp.17,24, 27-30 March 2012

[Perez-Rodriguez, 2012] Perez-Rodriguez, R., Fontenla-Gonzalez, J., Caeiro-Rodriguez, M., 2012. The Three Dimensions of Flexibility in the GameTel Project. In: Handbook of Research on Serious Games as Educational, Business and Research Tools. No. Hershey, PA, USA. IGI Global, pp. 750–768.

[Petridis, 2012] Petridis, P., Dunwell, I., Panzoli, D., Arnab, S., Protopsaltis, A., Hendrix, M., & de Freitas, S. (2012). Game engines selection framework for high-fidelity serious applications. International Journal of Interactive Worlds, 2012, 1-19.

[Pew Research Center, 2012] Pew Research Center, The Future of Gamification http://pewinternet.org/Reports/2012/Future-of- Gamification.aspx

[Piaget, 1929] Piaget, J., "The Child's Conception of the World". Harcourt, New Your, 1929

[Pirovano, 2013] M. Pirovano, P.L. Lanzi, R. Mainetti, N.A. Borghese, IGER: A Game Engine Specifically Tailored to Rehabilitation, in: Games for Health Europe. Amsterdam, 2013.

[Popescu, 2011] Popescu, M. M., Romero, M., Usart, M., National, C. I., 2011. Using Serious Games in adult education Serious Business for Serious Peoplethe MetaVals game case study. In: Proceedings of the 7th International Conference on Virtual Learning - ICVL 2012. pp. 68–72.

[Pranantha, 2012] D. Pranantha, F. Bellotti, R. Berta, A. De Gloria, A Format of Serious Games for Higher Technology Education Topics, in: 12th IEEE International Conference on Advanced Learning Technologies (ICALT). Rome, 2012.

[Prensky, 2003] Prensky M., "Digital game-based learning", ACM Computers in Entertainment, vol. 1, no. 1, 2003.

[Preston, 2014] J. A. Preston, Serious Game Development: Case Study of the 2013 CDC Games For Health Game Jam, in: Proceedings of the 2014 ACM International Workshop on Serious Games, 2014

[Qin, 2010] J. Qin, Y. Chui, W. Pang, K. Choi, P. Heng, Learning Blood Management in Orthopedic Surgery through Gameplay, Computer Graphics and Applications, IEEE, vol. 30, no. 2, March-April, 2010, 45-57

[Riedel, 2011] Riedel, J; & Baalsrud Hauge, J. State of the Art of Serious Gaming for Business and Industry, 17th International Conference on Concurrent Enterprising: Collaborative Environments for Sustainable Innovation, 20-22 June 2011, Aachen, Germany, Centre for Operations Management, RWTH Aachen, Aachen.

[Rowe, 2010] Rowe, J. P., Shores, L. R., Mott, B. W., Lester, J. C. Individual Differences in Gameplay and Learning: A Narrative-Centered Learning Perspective. In Proceedings of the Fifth International Conference on the Foundations of Digital Games (FDG), Monterey, CA, 2010.

[Salazar, 2012] M. G. Salazar, H. A. Mitre, C. Lemus Olalde and J. L. González Sánchez, Proposal of Game Design Document from software engineering requirements perspective, Computer Games (CGAMES) 2012, 17th International Conference on, 2012, 81-85

[Sawyer, 2008] Sawyer B., Smith P., “Serious Game Taxonomy”, Paper presented at the meeting Serious Game Summit 2008, Game Developer Conference, 2008

[Shah, 2016] H. Shah, K. Warwick, J. Vallverdú, D. Wu, Can machines talk? Comparison of Eliza with modern dialogue systems, Computers in Human Behavior, Volume 58, May 2016, 278-295

[Shea, 2013] Shea, R., Liu, J., Ngai, E. H., & Cui, Y. (2013). Cloud gaming: architecture and performance. Network, IEEE, 27(4).

[Sliney, 2008] A. Sliney, D. Murphy, Jdoc: A Serious Game for Medical Learning, in: Proc. International Conference on Advances in Computer-Human Interaction, 2008, 131-136

[Sprott, 2004] Sprott, D.,Wilkes, L., 2004. Understanding service-oriented architecture. The Architecture Journal 1 (1), 10–17.

[Swarz, 2010] Swarz, J., Ousley, A., Magro, A., Rienzo, M., Burns, D., Lindsey, A.M., Wilburn, B., Bolcar, S., , "CancerSpace: A Simulation-Based Game for Improving Cancer-Screening Rates," Computer Graphics and Applications, IEEE , vol.30, no.1, pp.90-94, Jan.-Feb. 2010

[Sweetser, 2005] Sweetser P. and Wyeth P., "GameFlow: A Model for Evaluating Player Enjoyment in Games," ACM Computers in Entertainment, vol. 3, no. 3, July 2005.

[Sweller, 1988] Sweller, J. "Cognitive load during problem solving: Effects on learning". Cognitive Science 12 (2), 1988.

[Tashiro, 2009] Tashiro J., What really works in serious games for healthcare education, Conference on Future Play on @ GDC Canada, Vancouver, British Columbia, Canada, 2009.

[Tong, 2015] T. Tong, V. Guana, A. Jovanovic, F. Tran, G. Mozafari, M. Chignell, E. Stroulia, Rapid Deployment and Evaluation of Mobile Serious Games: A Cognitive Assessment Case Study, Procedia Computer Science, Volume 69, 2015

[Torrente, 2009] Torrente, J., del Blanco, A., Moreno-Ger, P., Mart´ınez-Ortiz, I., Fern´andez-Manj´on, B., 2009. Implementing accessibility in educational videogames with e-Adventure. In: MTDL ’09. ACM, New York, NY, USA, pp. 57–66.

[UPA, 2008] UPA Usability Professionals’ Association, What is UCD, 2008, available online at: http://www.usabilityprofessionals.org/usability_resources/about_usability/what_is_ucd.html.

[Ushaw, 2015] G. Ushaw, R. Davison, J. Eyre, and G. Morgan. 2015. Adopting Best Practices from the Games Industry in Development of Serious Games for Health, In: Proceedings of the 5th International Conference on Digital Health, 2015

[Vatrapu, 2013] Vatrapu, R., Kickmeier-Rust, M., Bull, S., Johnson, M., Hammermueller, K., Byrne, W., Hernandez-Munoz, L., Giorgini, F., Meissl-Egghart, G., 2013. Learning, Learning Analytics, Activity Visualisation and Open Learner Model: Confusing? In: Hern´andez-Leo, D., Ley, T., Klamma, R., Harrer, A. (Eds.), Scaling up Learning for Sustained Impact SE - 51. Vol. 8095 of Lecture Notes in Computer Science. Springer Berlin Heidelberg, pp. 532–535

[Wasson, 2012] S.,Wasson, Bull, B., Kickmeier-Rust, M., Johnson, M., Moe, E., Hansen, C., Meissl-Egghart, G., Hammermuller, K., 2012. Assessing English as a Second Language: From Classroom Data to a Competence-Based Open Learner Model. In: International Conference on Computers in Education.

[Watkins, 1998] Watkins, R., Leigh, D., Foshay, R. and Kaufman, R., “Kirkpatrick Plus: Evaluation and Continuous Improvement with a Community Focus”, Educational Technology Research & Development, vol. 46, no. 4, 1998.

[Wendel, 2013] Wendel V., Gutjahr M., Göbel S., and Steinmetz R.. 2013. Designing collaborative multiplayer serious games. Education and Information Technologies 18, 2 (June 2013)

[Yessad, 2010] A. Yessad, J.M. Labat, F. Kermorvant, SeGAE: A Serious Game Authoring Environment, in: 10th IEEE International Conference on Advanced Learning Technologies. Sousse, 2010.

[Zielke, 2012] Zielke M. A., Evans M. J., Dufour F., Christopher T. V., Donahue J. K., Johnson P., Jennings E. B., Friedman B. S., Ounekeo P. L., Flores R., "Serious Games for Immersive Cultural Training: Creating a Living World," IEEE Computer Graphics and Applications, vol. 29, no. 2, pp. 49-60, Mar./Apr. 2009.

[Zyda, 2003] Zyda, M.; Hiles, J.; Mayberry, A.; Wardynski, C.; Capps, M.; Osborn, B.; Shilling, R.; Robaszewski, M.; Davis, M., "Entertainment R&D for defense," Computer Graphics and Applications, IEEE , vol.23, no.1, pp.28,36, Jan/Feb 2003

[Zyda, 2005] Zyda M.. "From visual simulation to virtual reality to games". IEEE Computer, September 2005.